INFLUENCE OF METALLICS AND EAF TYPE ON SPECIFIC CONSUMPTIONS AND PRODUCTIVITY*

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Resumo

O trabalho está baseado na análise de dados de perto de 200 fornos elétricos a arco de diferente *design*: convencional, de corrente contínua, de carcaças gémeas, com preaquecimento de sucata no transportador ou em *shaft*, etc. Incluem-se fornos que processam principalmente sucata, e fornos com carregamento parcial de gusa sólido ou líquido, ferro briquetado a quente (HBI) ou ferro esponja (DRI) a frio ou a quente. São avaliados os consumos de energia elétrica, oxigênio, gás natural e materiais carbonosos; os tempos entre vazamentos, com forno ligado e com forno desligado, assim como a produtividade horária. Com os dados obtidos, se analisa a influência dos metálicos (e seu estado térmico ao momento do carregamento), e o *design* do forno, sobre os consumos específicos mencionados e a produtividade.

Palavras-chave: Forno eléctrico a arco; Metálicos; Benchmarking; Preaquecimento de sucata; Consumo de energia; Produtividade.

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Abstract

The paper is based on analysis of data od around 200 EAFs of different design: conventional, DC, twin shell, with scrap preheating in conveyor or shaft, etc.. Included in the survey are furnaces charging mostly scrap, and others charging (partially) hot metal, pig iron, HBI, or cold / hot DRI. The assessment includes power, oxygen natural gas and carbon consumption; tap-to-tap time, power-on time and power-off time, as well as hourly production. With the collected data, the influence of metallics (and their thermal state at charging), and furnace design, on specific consumptions and productivity are discussed.

Keywords: Electric arc furnace; Metallics; Benchmarking; Scrap preheating; Power consumption; Productivity.

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1 INTRODUCTION

There is an important variation in scrap quality and alternative iron sources depending on country and region. Besides, a variety of furnace designs are available. This paper intends to look at the influence of metallics type and EAF design on specific consumption of energy, oxygen and other inputs, as well as on some productivity indicators, based on a survey of published figures of EAFs around the world. The results obtained are analyzed in detail.
The data base was selected from publications in technical journals and presentations in conferences, since 2010 to February 2017. All furnaces included are intended for production of rolled products: EAFs for steel castings, forgings and powder are not included, as well as furnaces producing exclusively stainless and tool steels. Also excluded are furnaces with heat capacity lower than 30 t.
The universe surveyed includes 190 furnaces. Twin shell furnaces are counted as one furnace (including the CONARC furnaces). All steelmaking regions are included (Figure 1). Charge types include from 100% scrap to 40% pig iron, 60% hot metal, 100% DRI/HBI and 100% hot DRI. Products include merchant long products, SBQ, flat products (coil and plate) and seamless pipes.

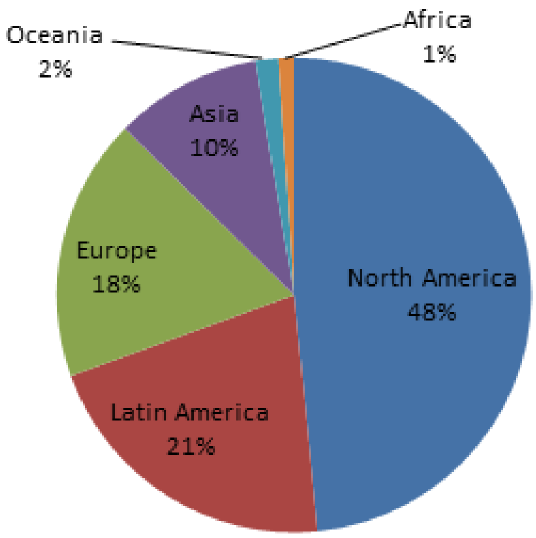

Figure 1. Distribution of the surveyed furnaces by region.

The survey includes 28 DC vs. 162 AC furnaces. Regarding tapping system, there are 16 furnaces equipped with spout, and 174 with EBT. 31 furnaces have some form of scrap preheating (15 Consteeel, 5 shaft and 11 twin shell furnaces), while the other 159 furnaces have no scrap preheating at all. In terms of charging, 9 furnaces are known to be single bucket. In Figure 2, the distributions of these furnace features within the survey are shown.
The relation between transformer power and heat capacity within the survey is shown in Figure 3. The line in the figure shows the 1:1 ratio.

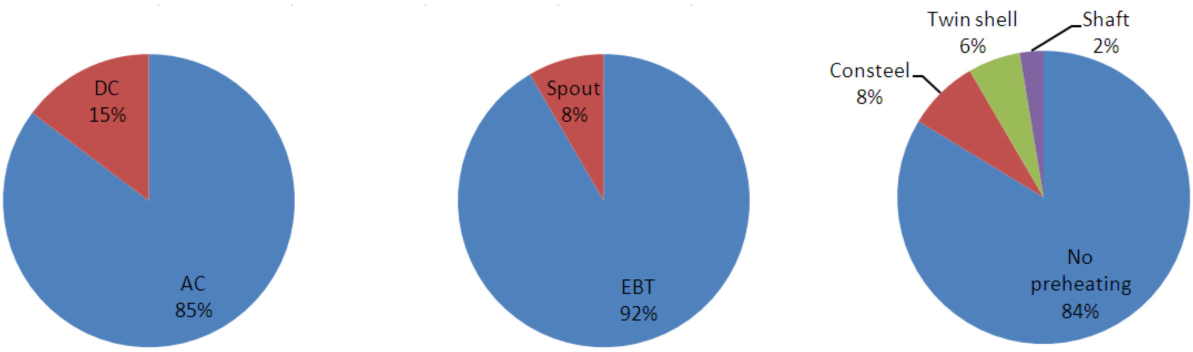

Figure 2. Distribution of furnace type within the survey. Left: electric current type; center: tapping system; right: no preheating and preheating systems.

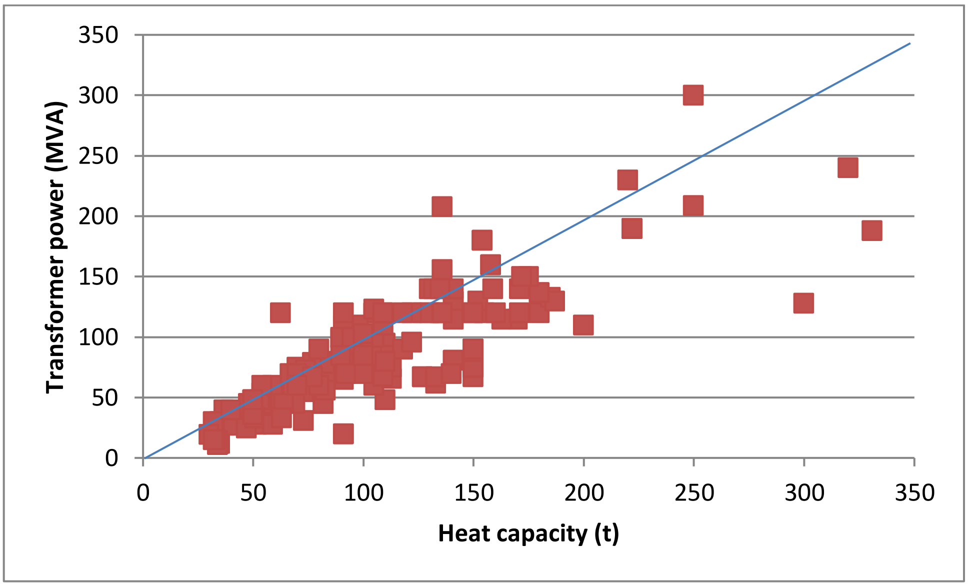

Figure 3. Transformer power and heat capacity (steel in the ladle) for the surveyed furnaces. The blue line indicates a 1:1 ratio.

Specific consumptions are expressed in terms of metric tons of liquid steel in the ladle. The data included are: company / group; plant name; country; EAF type, heat capacity; transformer (power in MVA); electrode diameter; productivity; tap to tap time; power on time; power consumption, oxygen consumption; injected carbon consumption; natural gas consumption; electrodes consumption; metallic yield; charge type; product type; published reference.
The sources of the information can be found in the references of this paper [1-46]. It is obvious that published data corresponds usually to a specific operation period, and consumption figures as well as productivity times change depending on demand and other situations that may vary along time.

2 POWER CONSUMPTION

For the population of surveyed furnaces, the specific consumption of electric energy depends first of the raw materials, and the thermal state of them when charged (hot DRI, hot metal). Of the ten top EAFs with the lowest energy consumption (<300 kWh/t), nine charge more than 20% of hot metal (Table 1 and Figure 1). In these

cases, energy is consumed in the blast furnace, and EAF CO_2 emissions are larger than usual.
The furnaces charging an important share of pig iron, as well as those charging scrap that are managed more efficiently, have a specific energy consumption of 300 - 400 kWh/t (Figure 4).
Then, those furnaces of intermediate efficiency with scrap-based metallic charge, as well as those charging hot DRI, are located in the range of 400 – 450 kWh/t (figure 4). Higher energy consumption (more than 450 kWh/t) is typical of high cold DRI/HBI share or of low efficiency scrap-based EAFs.
A favorable influence of scrap preheating is observed (Figure 5). Consteel, shaft furnaces and twin shell furnaces are located within those with lower power consumption, sharing this position with the more efficient conventional EAFs. For this purpose, to eliminate the aforementioned influence of the metallic charge, only those EAF charging 80% of scrap or more were considered.

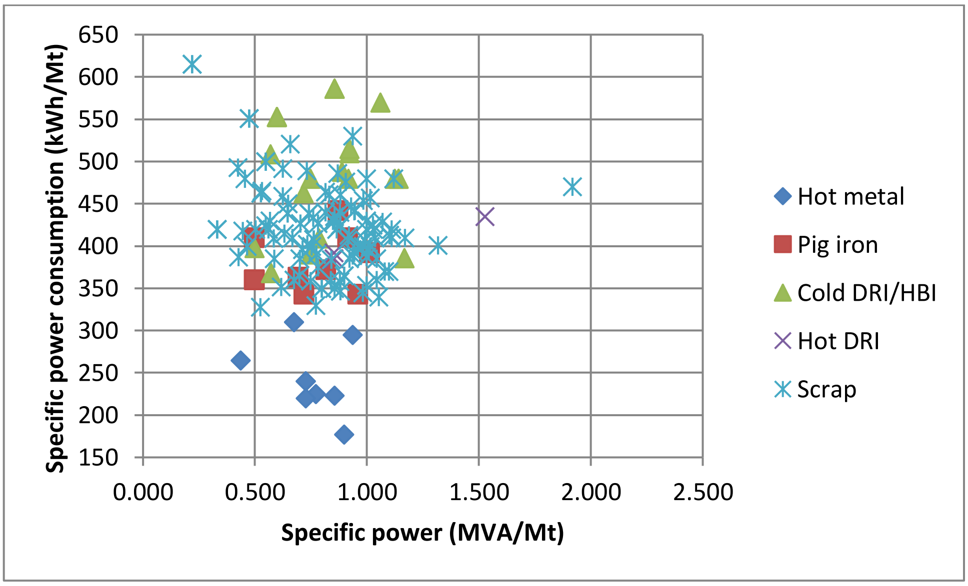

Figure 4. Specific power consumption for furnaces with different metallic charge. Scrap-based EAF applies for furnaces charging more than 80% scrap. Hot metal charging furnaces are considered those charging 20% or more hot metal.

3 OTHER FACTORS

3.1 Oxygen consumption. The distribution of specific oxygen consumption in the surveyed furnaces is shown in figure 6. More than half of the surveyed furnaces consume 30 to 40 Nm^3/t of oxygen. This reflects the advance of chemical energy, due to productivity and power cost. From a technological point of view, this is associated to the use of injectors instead of lances, as well as the changes in injector design to allow for large oxygen flow rate.

Table 1. Top twenty furnaces regarding power consumption. HM: hot metal; PI: pig iron; cDRI: cold DRI. LS: Long special; LC: Long carbon; SP: Seamless pipes; FC: Flat carbon.

Country	Heat capacity (t)	Current	Type	Transformer (MVA)	Tap to tap (min)	Power cons. (kWh/tls)	O_2 (Nm^3/tls)	Met. other than scrap (%)	Product
China	50	AC	Standard		67	132		54 HM	LS
China	100	DC	Standard	90	44	177	47	57.5 HM	LS
China	110	AC	Standard	80	33	220	33	30 HM	LS
Russia	175	AC	Standard	150	45	223	34	22 HM	LC
Taiwan	155	AC	Twin Shell	120	44	225	37	35 HM	LC
China	110	AC	Standard	80	35	240	33	30 HM	SP
China	110	AC	Standard	80	35	240	33	30 HM	SP
Brazil	110	AC	Standard	48	43	265		30 HM	LC
Brazil	80	AC	Standard	75		295	31	25 HM/5PI	LC
Singapore	80	AC	Shaft		48	295		0	LC
Turkey	195	AC	Standard		47	300	38,5	0	LC
South Africa	170	AC	Conarc	115	57,5	310	43	50 HM/ 50 cDRI	FC
India	180	AC	Conarc	137	57,5	310		50 HM/50 cDRI	FC
Korea	120	AC	Shaft		49	314	31	not known	LC
Vietnam	63	AC	Consteel	33	54	328		10 HM	LC
Mexico	110	AC	Standard	85	90	330		7 cDRI	LC
Italy	95	AC	Standard	100	42	340	20	10 PI	SP
Brazil	50	AC	Standard	36		343	60	30 PI	LC
Brazil	50	AC	Standard	48		343	60	30 PI	LC
Mexico	56	AC	Standard	55	55	345		7 cDRI	LC

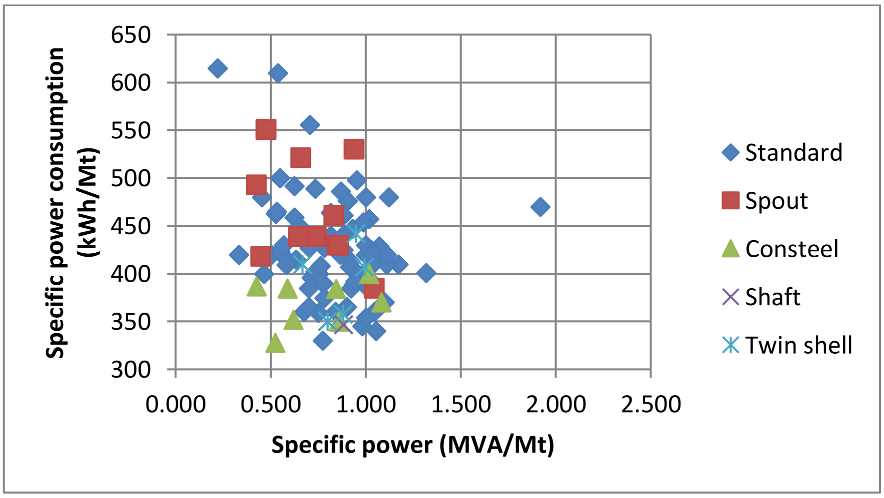

Figure 5. Specific power consumption for scrap preheating and conventional furnaces. Only furnaces charging 80% scrap or more are considered.

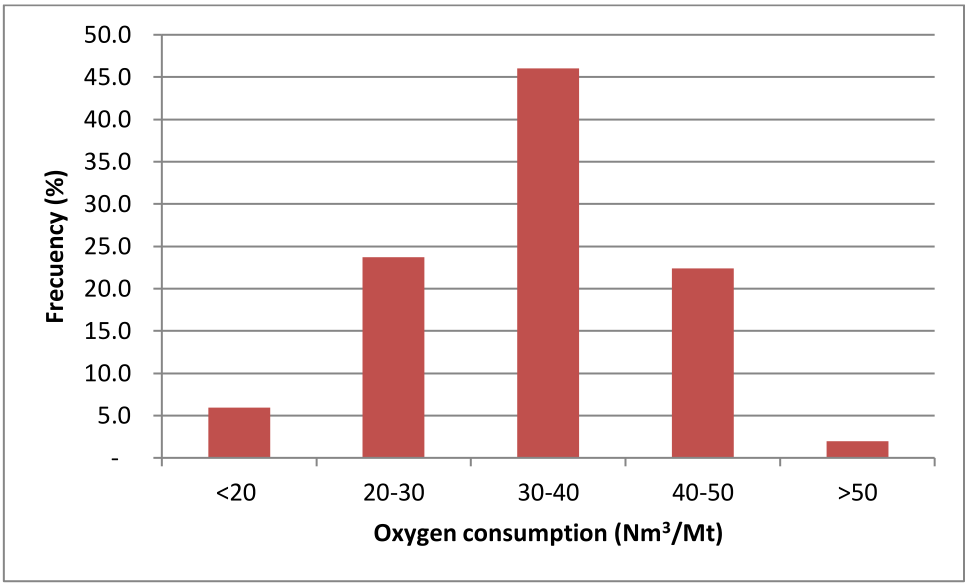

Figure 6. Specific oxygen consumption in Nm^3/t for the EAF surveyed.

Although there is a large dispersion, it is worth to mention the average oxygen consumption related to the metallics charged:

- 20% or more of hot metal: 36.3 Nm^3/t
- 20% or more of pig iron: 43.3 Nm^3/t
- 20% or more of DRI/HBI: 31.7 Nm^3/t
- 80% or more scrap: 31.7 Nm^3/t

3.2 Electrodes. As is to be expected, the higher the heat capacity, the larger the electrode diameter (Figure 7). But two other aspects can be mentioned:

- There is a big concentration of furnaces using 610 mm diameter electrodes, tapping from 70 to 200 t per heat.
- DC furnaces, with one or two electrodes, present the larger diameter, for a given heat capacity.

As is to be expected, there is a trend to increased electrode consumption for higher power consumption (Figure 8). DC furnaces display a lower electrode consumption.

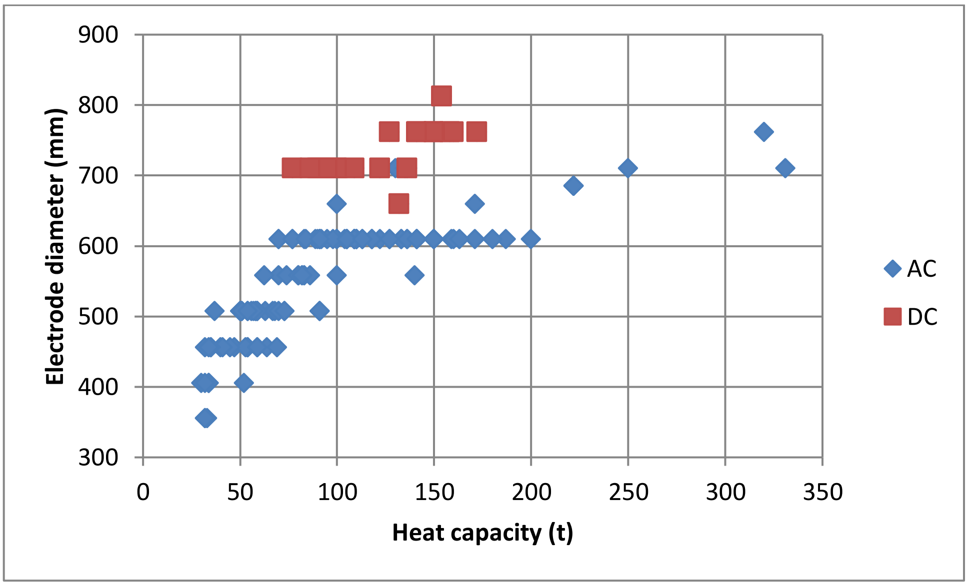

Figure 7. Electrodes diameter vs. heat capacity, for AC and DC furnaces of any design and metallic charge.

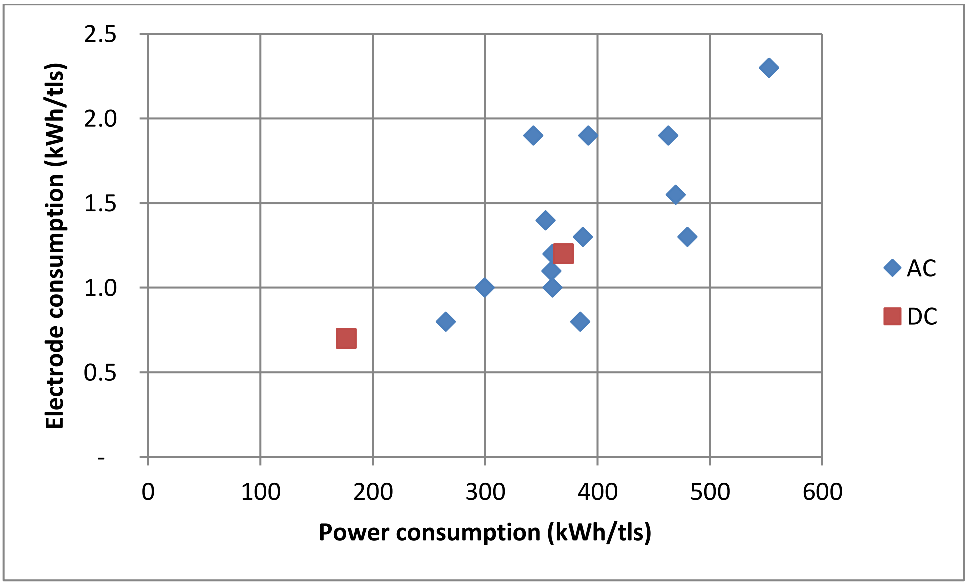

Figure 8. Electrode consumption vs. energy consumption for AC and DC furnaces.

Productivity. Productivity per hour is linearly related to the heat size, although other factors influence, too (figure 9). Seven of the ten top EAFs in productivity per hour are feeding slab casters.

Regarding power on time, the twenty top EAFs have a varied heat size (35 to 220 t); sixteen of them are dedicated to merchant long products. The logic behind this situation is that in general, this furnaces are linked to billet casters equipped with metering nozzle and oil lubrication, characterized by casting speeds well higher than those used for SBQ, for the same billet size. Long sequences are usual for these casters, most of them equipped with automatic nozzle changer. SBQ casters, instead, have limited sequence length because of shorter SEN life and a larger variety of steel grades. See Table 2

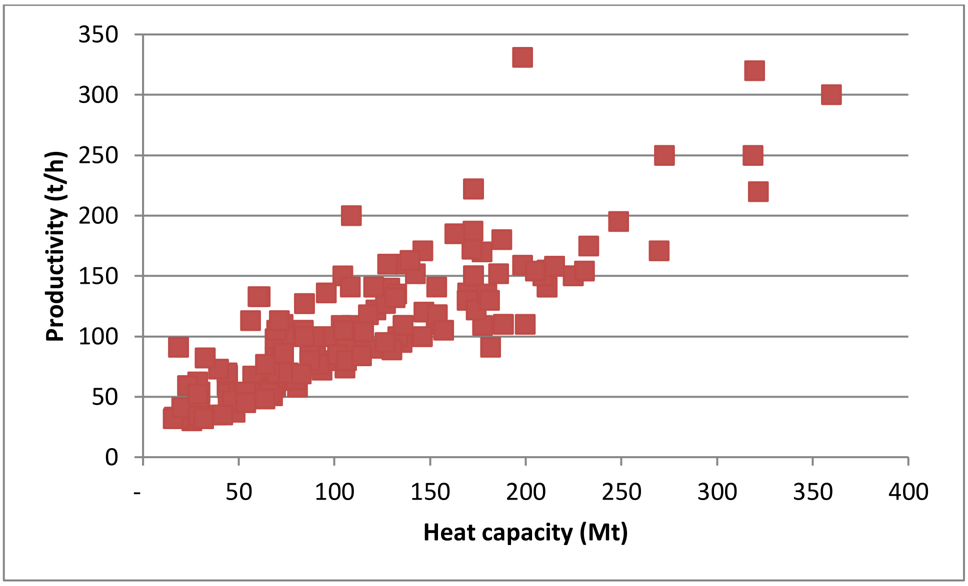

Figure 9. Hour production versus heat capacity, for all EAFs.

4 CONCLUSIONS

There has been four ranges of power consumption according to the metallic charge:
<300 kWh/t: furnaces charging more than 20% of hot metal
300-400 kWh/t: furnaces charging an important share of pig iron, as well as those charging scrap that are managed more efficiently
400 – 450 kWh/t: furnaces of intermediate efficiency with scrap-based metallic charge, and those charging hot DRI
>450 kWh/t: furnaces with high cold DRI/HBI share or low efficiency scrap-based EAFs.
Regarding furnace type, it is clear the favorable influence of scrap preheating, with transporter, shaft or twin shell. DC EAFs do not differ much on power consumption, but are in the lower range of electrode consumption.

Table 2. Twenty plants in the survey, with the shorter power on time. HM: hot metal; PI: pig iron; cDRI: cold DRI. LS: Long special; LC: Long carbon; SP: Seamless pipes; FC: Flat carbon.

Country	Heat cap. (t)	Current	Type	Transformer (MVA)	Tap to tap (min)	Power on (min)	Power cons. (kWh/tls)	O_2 (Nm^3/tls)	Metallics other than scrap	Product
Spain	130	AC	Standard	140	43	29			SC	LC
Germany	100	AC	Standard	90	41	30	365	38,6	SC	LC
Germany	100	AC	Standard	90	41	30	365	38,6	SC	LC
Belgium	90	DC	Standard	99	42	31	370	44	SC	LC
Russia	175	AC	Standard	150	45	32	223	34	HM	LC
USA	35	AC	Consteel	30	55	32	350	31	SC	LC
USA	171	AC	Shaft/ Twin	140	38	32	372	50	PI	FC
Brazil	110	AC	Standard	48	43	33	265		HM	LC
Norway	89	AC	Consteel	75	41	33	384	26	SC	LC
Turkey	220	AC	Standard	230	41	35	360	35	SC	LC
USA	154	DC	Standard	180	40	35	386	41	CDRI	FC
USA	154	DC	Standard	180	45	35	386	41	CDRI	FC
Luxemburg	160	DC	Twin Shell			35			SC	LC
China	100	DC	Standard	90	44	36	177	47	HM	LS
Brazil	80	AC	Standard	75		37	295	31	HM	LC
Korea	100	AC	Standard	100	45	37	354	29	SC	LC
France	92	DC	Standard	72	54	37	375	44	SC	LC
UAE	152	AC	Standard	130	64	37	392	35	HDRI	LC
Belarus	110	AC	Standard	95		38	386		SC	LC
Qatar	85	AC	Standard	78	50	38	480	35	CDRI	LC

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