Benchmark study of the EAF plants using KT injection system

(Case of long products – carbon steel production)

F. Memoli, V. K. Koester, C. Giavani

In the last five years the amount of oxygen used into the Electric Arc Furnace has increased a lot. This fact depends, especially in areas like Western Europe, on the high cost of the electrical energy, but in general this increase can also be explained with the development of new injection technologies, which have increased the efficiency on the thermal and chemical input into the EAF.
In addition to that, the multipoint injection of supersonic oxygen and powder carbon around the EAF, has also given the possibility to automate the melting and refining operations, so that nowadays the furnace operator can perform only supervision activities to the melting and refining process. No risk of human errors, for instance over-oxidation with manual operated lances, is anymore present. One of these injection technologies, KT Injection System, a product of Techint Technologies, has performed a very big development during the last two years, with more than twenty projects started up worldwide.
In this paper it is presented the benchmark study of the performances, which have been achieved in the plants where KT Injection System has been installed.
Comparisons between the situation before and after the installation, on all the major parameters of the EAF, give interesting information on injection efficiencies and furnace sustainable productivity increases.

Keywords: steel, decarbonization, steelmaking, technology

INTRODUCTION TO THIS BENCHMARK STUDY

This benchmark is the updating the first study issued one year ago, which was considering a number of 40 Electric Arc Furnaces placed in 9 different areas of the world. The number of plants now considered has raised up to 66 in the same areas, giving even more consistency to the result of the research.
Benchmarking Electric Arc Furnaces it's a difficult task, taking into account the big number of variables that can effect EAF operation. One approach to accomplish this kind of study is the standardization of some parameters, to be able to finalize a comparison
In this study, the purpose is to compare EAF plants producing mainly carbon steel (rebar and in general not high quality steel) and then comparing the result with similar plants that have introduced the KT Injection System – the multipoint chemical package of Techint Technologies.
All plant data used in this second benchmark study has been collected during 2003 and 2004, so the study refers to the present situation of those plants.
It is not the intention of this paper to get to general conclusions regarding average energy consumption or average productivity for a typical Electric Arc Furnace.
It's commonly agreed that in the Steel Industry, and in particular in the EAF field, it's difficult to determine the best energy consumption or productivity, due to the big quantity of direct factors (scrap type, furnace design, manpower, etc) and indirect factors (plant efficiency, market conditions for scrap and billets, etc) influencing the liquid steel production. Apart for this general considerations, this benchmark can be useful to overview the different operational figures in many plants, an opportunity that is not always frequent and can be useful to make simple comparisons.
The name and the location of the plants object of this benchmark are not disclosed, due to obvious confidential reasons.

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BENCHMARK OF EAFs PRODUCING CARBON STEEL FOR LONG PRODUCTS: GEOGRAPHIC DISTRIBUTION

The EAF considered in this second benchmark are 66, located in 9 different geographical areas and producing as average about 500,000 metric tons per year. Total production considered is about 30 million of tons. The majority of these plants are producing carbon steel with no special quality requirement and all of them are in the Long Products market. In Table 1 it is indicated the location of the plants considered in the old benchmark of 2003 and in this new Benchmark 2004:

PLANTS	Benchm. 2003	Benchm. 2004
Europe	14 (35%)	30 (45,5%)
United States	10 (25%)	12 (18,2%)
Brazil	4 (10%)	5 (7,6%)
China	3 (7,5%)	5 (7,6%)
South East Asia	3 (7,5%)	4 (6,1%)
Central America	2 (5%)	3 (4,5%)
South Africa	2 (5%)	3 (4,5%)
Japan	1 (2,5%)	3 (4,5%)
Middle East	1 (2,5%)	1 (1,5%)
TOTAL	40	66

Table 1 *Tabella 1*

There is no particular reason for this distribution but the availability of consistent statistics about the Electric Arc Furnaces. This geographic distribution is not reflecting the

AREA	%
Europe (UE and others)	22
North America (USA and Canada)	11
Central America and Mexico	2
South America	4
C.I.S. (Russia and others)	11
Africa	2
Middle East	1
China	25
Japan	11
Other Asia	10
Oceania	1

Table 2 *Tabella 2*

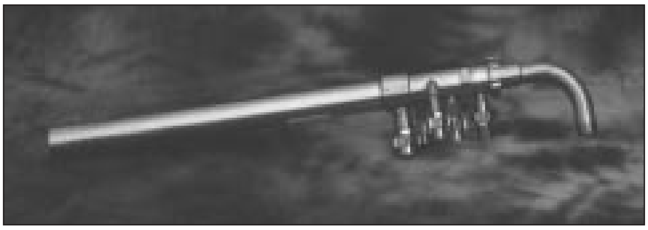

Fig. 1 – KT Oxygen Lance, a product of Techint.

Fig. 1 – Un prodotto di Techint: la lancia ossigeno.

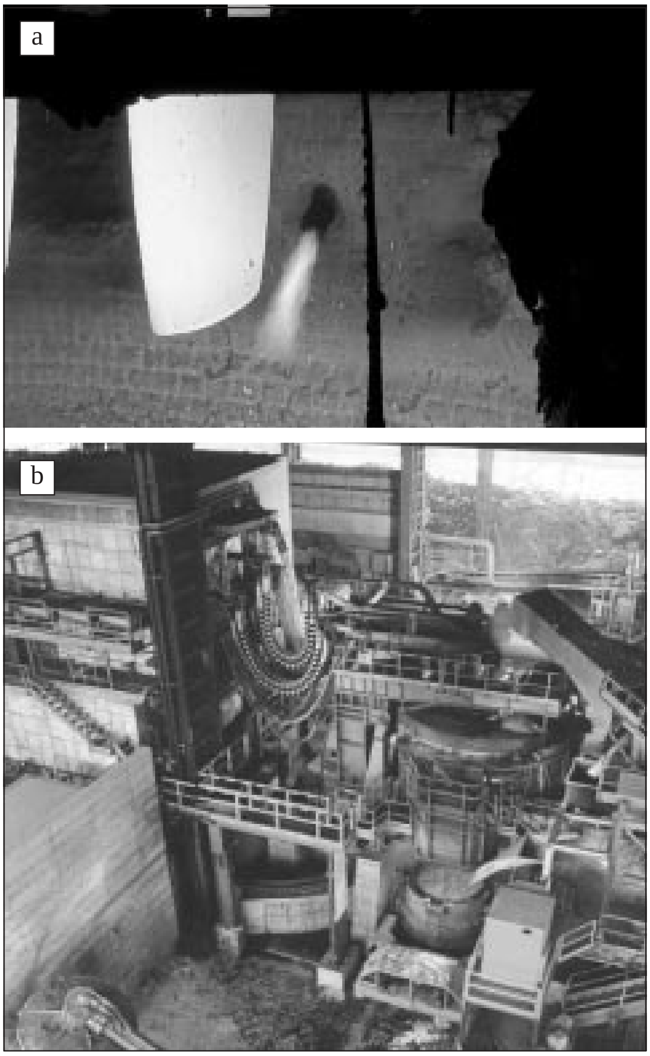

Fig. 2 – a) Typical locations of KT Lance; b) view of a Techint Technology EAF in operation.

Fig. 2 – a) Posizione tipica della lancia KT; b) vista di un forno Techint in funzione.

carbon steel production in the World (see table 2), nor the global steel production in the World, as a matter of fact China represents only the 7.5% of this study and a big market like C.S.I. is not included in this benchmark due to the fact that it was not available consistent data to include. Since the European and North America together represent in this benchmark the 63.7% of the data considered, we can consider this benchmark focused on these two areas with some influence coming from the rest of the world.

Just for reference we include here (table 2) the world steel production in percentage (Source Worldsteel.org, last updated 18 Jun 2004).

ELECTRIC ARC FURNACE STATISTICS

In Table 3 the data considered for the benchmark are summarized, as it is not possible to release all the single records. The figures, per each steel plant, have been selected as Monthly Averages of consecutive months of 2003 and/or 2004, at least one complete month of data.

Therefore these data can be considered representative of each one of the forty plants studied.

For each of the itemized figures, we have indicated the minimum value registered, the maximum value registered, the average value and the standard deviation of the forty plants, just to give a summary indication of the group of plants considered.

We reproduce also the table of Benchmark referred to 2003 (Table 3), the previous study to this one, to permit a sort of comparison between the two different studies.

A first remark is referred to the difference between the two benchmarks indicated; in the study of 2004 the "typical" furnace has a slightly reduced size (85 instead of 87 metric tons), a better yield (.87 instead of .86), a lower Tap to Tap time of about one minute and a lower electrical energy consumption (427 instead of 433 kWh/ton).

For what concerns the Standard Deviation, it is important to remark that their high value are the clear evidence that there is not uniformity of performances for this kind of production of steel worldwide.

The average consumption figures above are representing a yearly production of about thirty million of metric tons of liquid steel. For instance, the electrical energy consumption is 427 kWh/metric tons.

Even if there are plants in this group consuming only around 300 kWh/t, the global average is much higher: so it is true that the trend is to go below 400 kWh/t, but at the present time this target has not been reached yet for the majority of the plants.

The same consideration can be done for the electrode consumption: this value is decreasing in Europe and sometimes in the United States below 2 kg/t, thanks to the improvements of foamy slag practice and the electrode quality, but even in other countries - with no first-quality suppliers - consumption figures are decreasing thanks to the introduction of a foamy slag practice. Anyhow, even if there are some plants consuming 0,9 or 1,0 kg/t in AC furnaces, there are still plants that have electrode consumptions over 3 kg/t, a value certainly high which probably depends on the age of the equipment used in such furnaces.

A different consideration must be done regarding the tapping temperature: in this group of plants considered, there are plants which can count on a LF for steel treatment before casting, and there are plants which have no LF, so they have to tap at high temperatures to prevent low temperatures during casting. As a matter of fact, even if a LF is very common equipment nowadays, there are still plants that are working without that, maintaining anyhow good production performances.

BENCHMARK 2003	Unit* Int.	Unit* US	Average Int.	Average US	Stdev	Minimum Int.	Minimum US	Maximum Int.	Maximum US
Total Charge	metric ton	short ton	101	111.8	41%	24.2	26.7	196.5	216.6
Heat size	metric ton	short ton	87	95.8	40%	21.3	23.5	160.0	176.4
Yield	%		0.86		4%	0.78		0.937	
Power On Time	Minutes		52		41%	30.0		160.0	
Power Off Time	Minutes		20		53%	6.0		46.0	
Tap to Tap Time	Minutes		72		40%	43.0		203.0	
Average Active Power	MW		46		41%	12.3		95.8	
El. Energy consumption	kWh/ton	KWh/st	433	393	15%	318	288	525	475
O_2 consumption	Nm³/ton	scft	32	1023	29%	18.0	416	50.0	1601
CH_4 consumption	Nm³/ton	scft	5	146	72%	0.0	0.0	13.0	416.5
Carbon consumption tot.	kg/ton	Lb/st	13	26	44%	4.0	8.0	31.0	62.0
FeO in slag content	%		34		25%	28.0		46.0	
Electrodes consumption	kg/ton	Lb/st	1.97	3.94	21%	1.0	2.0	3.1	6.2

BENCHMARK 2003	Unit* Int.	Unit* US	Average Int.	Average US	Stdev	Minimum Int.	Minimum US	Maximum Int.	Maximum US
Tapping Temperature	°C	°F	1640	2984	2%	1600	2912	1720	3128
Total Charge	metric ton	short ton	98	108.5	42%	24.2	26.7	196.5	216.6
Heat size	metric ton	short ton	85	93.6	41%	21.3	23.5	160.0	176.4
Yield	%		0.87		5%	0.78		0.937	
Power On Time	Minutes		51		39%	30.0		160.0	
Power Off Time	Minutes		20		76%	6.0		46.0	
Tap to Tap Time	Minutes		71		44%	43.0		203.0	
Average Active Power	MW		46		48%	12.3		95.8	
El. Energy consumption	kWh/ton	KWh/st	427	388	15%	298.0	270	575	517
O_2 consumption	Nm³/ton	scft	32	1023	28%	13.0	416	50.0	1601
CH_4 consumption	Nm³/ton	scft	4	117	86%	0.0	0.0	13.0	416.5
Carbon consumption tot.	kg/ton	Lb/st	13	26	42%	2.5	5.0	31.0	62.0
FeO in slag content	%		34.6		25%	28.0		46.0	
Electrodes consumption	kg/ton	Lb/st	1.92	3.84	45%	0,9	1.8	3.2	6.4
Tapping Temperature	°C	°F	1637	2978	2%	1600.0	2912	1720	3128

* Heat size and specific consumptions are referred to metric or short tons of tapped liquid steel

Table 3

Tabella 3

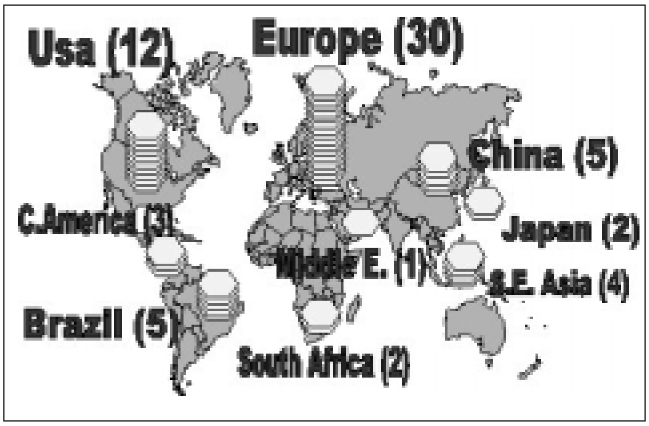

Fig. 3 – Geographical distribution of this Benchmark study 2004.

Fig. 3 – Distribuzione geografica di questo studio comparativo del 2004.

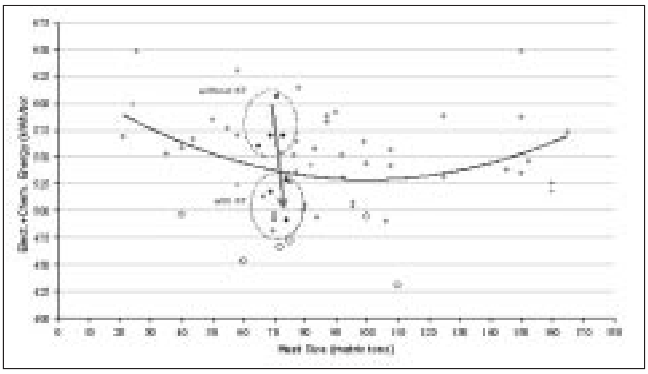

Fig. 4 – Total Energy Consumption Vs Heat size, the jump of some plants after KT Installation, Consteel® plants in blanks.

Fig. 4 – Consumi totali di energia rispetto al taglio di colata, il miglioramento di alcuni impianti dopo l'installazione delle lance KT; impianti Consteel® rappresentati con pallini bianchi.

BENCHMARK OF THE EAFs

To be in condition to compare data, all of them have been re-parameterized to the same tapping temperature: 1640°C, which is the average tapping temperature of all the plants (on the basis of 0,4 kWh/°C). Then, two parameters have been considered: the Total Energy Consumption and the Specific Productivity.

- Total Energy Consumption (kWh/t) is the sum of Electrical Energy consumption and Thermo-Chemical Energy consumption. To calculate the second factor, standard efficiencies have been given to Natural Gas (9,6 kWh/Nm³) and Oxygen (3,2 kWh/Nm³).
- Specific Productivity is the furnace net productivity – tons of liquid steel produced in the power-on time – divided per the total Furnace Power (electrical and chemical power, considering the same rates as before). Specific Productivity gives the indication of tons produced per hour per MW installed.

These two parameters constitute the y-axes of the following two graphs, where on the x-axe there is the Heat Size. Points in gray are the results of the calculation per each one of the plants, while points in dark-blue are the EAFs KT Injection System and matching the requirements for this benchmark, pointed out before and after the KT Installation. In addition to that we have included also (indicated with circles in the

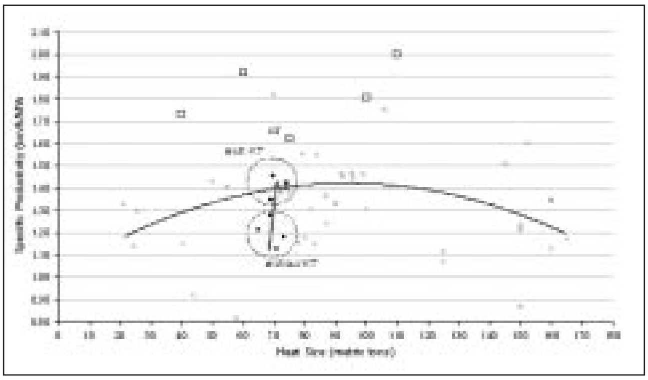

Fig. 5 – Specific Productivity Vs Heat size, the jump of some plants after KT Installation, Consteel® plants in blanks.

Fig. 5 – Produttività specifica rispetto alla taglia di colata, il salto di alcuni impianti dopo l'installazione delle lance KT; impianti Consteel® rappresentati con pallini bianchi.

Fig. 6 – Location plants.

Fig. 6 – Localizzazione degli impianti.

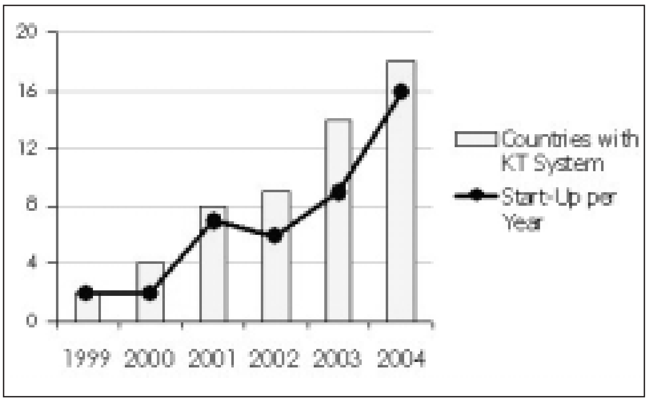

Fig. 7 – Growth of the KT Injection System Technology.

Fig. 7 – Crescita della tecnologia del sistema di iniezione KT.

graphs) the data relevant to the Consteel® Plants matching the requirements for this benchmark.
The result of the re-parameterisation and the following calculation indicates that:

- Average Total Energy consumption is 542.7 kWh/metric ton. Anyway in the graph we have indicated a trend line, which presents a minimum value around 100 tons and 527 kWh/t.
- Average Specific Productivity is 1.319 metric tons/hour/MW. Anyway in the graph we have indicated a trend line, which presents a maximum value around 95 tons and 1.430 tons/hour/MW
- If an EAF is above the Average Curve of Total Energy Consumption, introducing KT can jump below that curve, down of about 75 kWh per metric ton of liquid steel.
- If an EAF is below the Average Curve of Specific Productivity, introducing KT it can jump over that curve, at least of 0,25 metric tons per hour per MW installed.

KT INJECTION SYSTEM REFERENCES

KT Injection System it is used for Oxygen injection, Carbon injection, Lime injection, DRI Fines injection, Dust injection, powder White-Slag injection. In Table 4 it is reported the scope of work of each one of the projects of KT Injection System.

KT INJECTION SYSTEM: GROWTH AND EXPANSION

In Figure 7 it is shown the fast growth of the KT Injection System Technology – number of Project Start-Ups per Year - and the expansion Worldwide of this technology, testified by the number of Countries where Steel Plants are using the KT technology.

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Table 4 *Tabella 4*

	START UP	PLANT	COUNTRY	EAF TYPE	KT SYSTEM
44	Feb 2005 (under work)	SIDOR (Long Products), P.to Ordaz	Venezuela	EAF N.1, 150 ton 80% DRI	2 KT DRI Fines and Lime fines Injection
43	Feb 2005 (under work)	STEFANA, Ospitaletto (BS)	Italy	EAF AC, 130 ton 100% scrap	Complete Powder Injection Plant: 2 KT LF-Slag Injectors and K-Slag Plant
42	Dec 2004 (under work)	TIANJIN PIPE CORPORATION - TPCO, Tianjin	China	EAF AC#2, 150 ton 50% DRI	Complete system: 4 KT Oxy, 2 KT Carbon, TDR-H
41	Nov 2004 (under work)	WHEELING PITT. Pittsburgh PA	United States	EAF AC, 225 ton Consteel+Hot M.	Complete system: 5 KT Oxygen Lances, 4 KT Carbon Injectors, TDR-H
40	Oct 2004 (under work)	SIDOR (Flat Products), Puerto Ordaz	Venezuela	EAF N.2, 180 ton 80% DRI	Complete system: 3 KT Oxygen Lances, 2 KT Carbon Injectors
39	Sep 2004 (under work)	HENG LI, Ningxia Province	China	EAF AC, 75 ton Consteel system	Complete system: 3 KT Oxygen Lances, 3 KT Carbon Injectors, TDR-H
38	Sep 2004 (under work)	MSC, Mobarakeh Steel Complex	Iran	EAF N.8, 182 ton 100% DRI	Complete system: 3 KT Oxygen Lances, 3 KT Carbon Injectors, TDR-H
37	Sep 2004 (under work)	ACCIAIERIE DI SICILIA, Catania	Italy	EAF AC, 70 ton 100% scrap	Complete system: 3 KT Oxygen Lances, 3 KT Carbon Injectors
36	Aug 2004 (under work)	ACCIAIERIE VENETE, Padova	Italy	EAF AC, 85 ton 100% scrap	Complete system: 3 KT Oxygen Lances, 3 KT Burner/Carbon Injectors
35	Aug 2004 (under work)	ÄTORE STEEL, Ätore	Slovenia	EAF AC, 50 ton 100% scrap	Complete system: 3 KT Oxygen Lances, 3 KT Carbon Injectors, TDR-H
34	Aug 2004 (under work)	CISCO, Cape Town	South Africa	EAF AC, 45 ton 100% scrap	Complete system: 2 KT Oxygen Lances, 2 KT Carbon Injectors, TDR-H
33	Aug 2004 (under work)	PERWAJA STEEL SDN BHD, Kemaman	Malaysia	DC - EAF N.5, 75 ton, 90% DRI	Complete system: 4 KT Oxygen Lances, 2 KT Carbon Injectors
32	Jul 2004 (under work)	GERDAU DIVINOPOLIS, Divinopolis	Brasil	EOF, 40 ton 65% Hot Metal	KT Cooling Blocks installation
31	2004 (under work)	WEI CHIH, Kaohsiung	Taiwan R.O.C.	EAF AC, 100 ton Consteel system	Complete system: 3 KT Oxygen Lances, 3 KT Carbon Injectors, TDR-H
30	2004 (under work)	KOUZESTAN STEEL Corp. KSC, Ahwaz	Iran	EAF AC 185 ton, 80% DRI	Complete system, 3 KT Oxygen Lances, 3 KT Carbon Injectors
29	Apr 2004	WUXI XUEFENG IRON & STEEL CO. LTD., Wuxi	China	EAF AC, 75 ton Consteel system	Complete system: 3 KT Oxygen Lances, 3 KT Carbon Injectors, TDR-H
28	Mar 2004	GERDAU COSIGUA, Rio de Janeiro	Brazil	EAF AC, 100 ton 100% scrap	Furnace improvement 1 KT Oxygen Lance, 1 KT Carbon Injector
27	Jan 2004	SIDERURGICA SEVILLANA S.A., Riva Group, Sevilla	Spain	EAF AC, 90 ton 100% scrap	Furnace improvement: 1 KT Oxygen Lance + 2 KT Carbon Injectors
26	Dec 2003	CHIMET, Arezzo	Italy	SAF (Cu-Ar-Au), 3 ton, 100% powder	2 KT Oxygen Lances KT Cooling blocks
25	Dec 2003	TAMSA, Veracruz	Mexico	EAF AC, 150 ton 20% DRI	Complete system: 4 KT Oxygen Lances, 3 KT Burner/Car. Injectors

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	START UP	PLANT	COUNTRY	EAF TYPE	KT SYSTEM
24	Dec 2003	OJI, Gunma - Tokio	Japan	EAF AC, 80 ton 100% scrap	Complete system: 4 KT Oxygen Lances,2 KT Burner/Car.Injectors
23	Sep 2003	PROFILATI NAVE S.p.A., Montirone (BS)	Italy	EAF AC, 70 ton 100% scrap	System improvement: 4 KT Oxygen Lances, 2 KT Carbon Injectors, TDR-H
22	Aug 2003	PERWAJA STEEL SDN BHD, Kemaman	Malaysia	AC - EAF N.2, 75 ton, 90% DRI	Complete system: 2 KT Oxygen Lances, 2 KT Carbon Injectors
21	Aug 2003	DAVSTEEL, division of Cape Gate Pty Ltd, Vanderbijlpark	South Africa	EAF AC, 75 ton 15% DRI	System improvement: 4 KT Oxygen Lances, 3 KT Carbon Injectors, TDR-H
20	Jul 2003	MARIENH‹TTE, Graz	Austria	EAF AC, 45 ton 100% scrap	Complete system: 3 KT Oxygen Lances, 3 KT Carbon Injectors
19	Jun 2003	SIDOR (Long Products), Puerto Ordaz	Venezuela	EAF N.1, 150 ton 80% DRI	Complete system: 3 KT Oxygen Lances, 1 KT Carbon Injector
18	Mar 2003	GERDAU AMERISTEEL, Knoxville	United States	EAF AC, 55 ton Consteel system	Furnace improvement: 1 KT Carbon Injector
17	Dec 2002	PERWAJA STEEL SDN BHD, Kemaman	Malaysia	DC - EAF N.4, 75 ton, 90% DRI	Complete system: 4 KT Oxygen Lances, 2 KT Carbon Injectors
16	Dec 2002	FERRIERE NORD S.p.A, Osoppo, UD	Italy	EAF AC, 100 ton 100% scrap	System Improvement: 2 KT LF-Slag Injectors, TDR-H
15	Sep 2002	IRO Industrie Riunite Odolesi SpA, Odolo (Brescia)	Italy	EAF AC, 70 ton 100% scrap	System improvement: 4 KT Oxygen Lances, 2 KT Carbon Injectors
14	Aug 2002	RIVA ACCIAIO S.p.A., Verona	Italy	EAF AC N.2, 76 ton 100% scrap	Furnace improvement: 3 KT Burn/C/CaO, TDR-H
13	Aug 2002	RIVA ACCIAIO S.p.A., Verona	Italy	EAFAC N.1, 76 ton 100% scrap	Furnace improvement: 3 KT Burn/C/CaO, TDR-H
12	Jan 2002	EWK - EDELSTHAL Witten - Krefeld GmbH	Germany	EAF AC, 130 ton Stainless Steel	Complete system: 2 KT Oxygen Lances, 2 KT Carbon Injectors
11	Aug 2001	TENARIS DALMINE, Dalmine (Bergamo)	Italy	EAF AC, 97 ton 100% scrap	Complete system: 2 KT Oxygen Lances, 2 KT Carbon Injectors, TDR-H
10	Aug 2001	MAKSTIL A.D. - Duferco Group, Skopie	Macedonia	EAF AC, 110 ton 100% scrap	Complete system: 3 KT Oxygen Lances, 3 KT Carbon Injectors
9	Jun 2001	SIDERURGICA SEVILLANA S.A. - Riva Group, Sevilla	Spain	EAF AC, 90 ton 100% scrap	Furnace improvement: 2 KT Carbon Injectors
8	May 2001	TIANJIN PIPE CORPORATION - TPCO, Tianjin	China	EAF AC#1, 150 ton 50% DRI	Complete System: 3 KT Oxy Lances, 2 KT Carbon Injectors, 1 KT DRI-Fines Inj
7	Mar 2001	FERRIERE NORD S.p.A, Osoppo, UD	Italy	EAF AC, 100 ton 100% scrap	Furnace Improvement: 2 KT Lime Injectors
6	Jan 2001	DAVSTEEL, division of Cape Gate Pty Ltd, Vanderbijlpark	South Africa	EAF AC, 75 ton 15% DRI	Complete system: 3 KT Oxygen Lances, 3 KT Carbon Injectors, TDR-H
5	Jan 2001	IRO Industrie Riunite Odolesi SpA, Odolo (BS)	Italy	EAF AC, 70 ton 100% scrap	Complete System: 2 KT Oxygen Lances, 2 KT Carbon Injectors
4	Dec 2000	GEORGE FISCHER, Mettmann, (Düsseldorf)	Germany	Cupola Furnace Capacity 70t/h	New development: KT Spout Cooling Element
3	Oct 2000	PROFILATI NAVE S.p.A., Montirone (BS)	Italy	EAF AC, 70 ton 100% scrap	Complete System: 2 KT Oxygen Lances, 2 KT Carbon Injectors
2	Aug 1999	SIDENOR STEEL Co. SA, Thessalloniki	Greece	EAF AC, 75 ton 100% scrap	Furnace improvement: 1 KT Carbon Injector
1	Sep 1999	M.M.Z.	Moldova	EAF AC, 120 ton 100% scrap	Furnace improvement: 1 KT Carbon Injector

A B S T R A C T

STUDIO COMPARATIVO DELLE PERFORMANCES NEGLI IMPIANTI CHE UTILIZZANO IL SISTEMA DI INIEZIONE KT

Parole chiave: acciaio, decarburazione, acciaieria, tecnologie

Negli ultimi cinque anni la quantità di ossigeno usata nell'EAF è cresciuta notevolmente.
Questo situazione dipende, specialmente in aree come l'Europa Occidentale, dagli alti costi dell'energia elettrica, ma in generale questo incremento può anche essere spiegato con lo sviluppo di nuove tecnologie di iniezione che hanno aumentato l'efficienza termica e chimica nell'EAF.
In aggiunta a ciò, l'iniezione di ossigeno e carbone nell'EAF ha dato la possibilità di automatizzare la colata e affinare le operazioni, così da permettere all'operatore del forno di eseguire solamente le attività di supervisione alla colata e all'affinazione.
Non esiste più nessun rischio di errore umano, per esempio sovra-ossidazioni causate dall'uso improprio delle lance manuali.
Una di queste tecnologie di iniezione, KT INJECTION SYSTEM, un prodotto di Techint Technologies, ha effettuato un vero sviluppo durante gli ultimi due anni con più di 20 impianti operanti in tutto il mondo.
In questo paper presentiamo lo studio comparativo sulle performances che sono state raggiunte sugli impianti dove sono state installate le lance KT.
I paragoni tra la situazione prima e dopo l'installazione, su tutti i maggiori parametri dell'EAF, danno interessanti informazioni sull'efficienza dell'iniezione e sugli aumenti di produttività ottenuti dal forno.