Environmental control and the CONSTEEL process

By utilising off-gases to continuously preheat the scrap prior to charging, CONSTEEL offers a steelmaking technology that both lowers production costs and minimises environmental impact.

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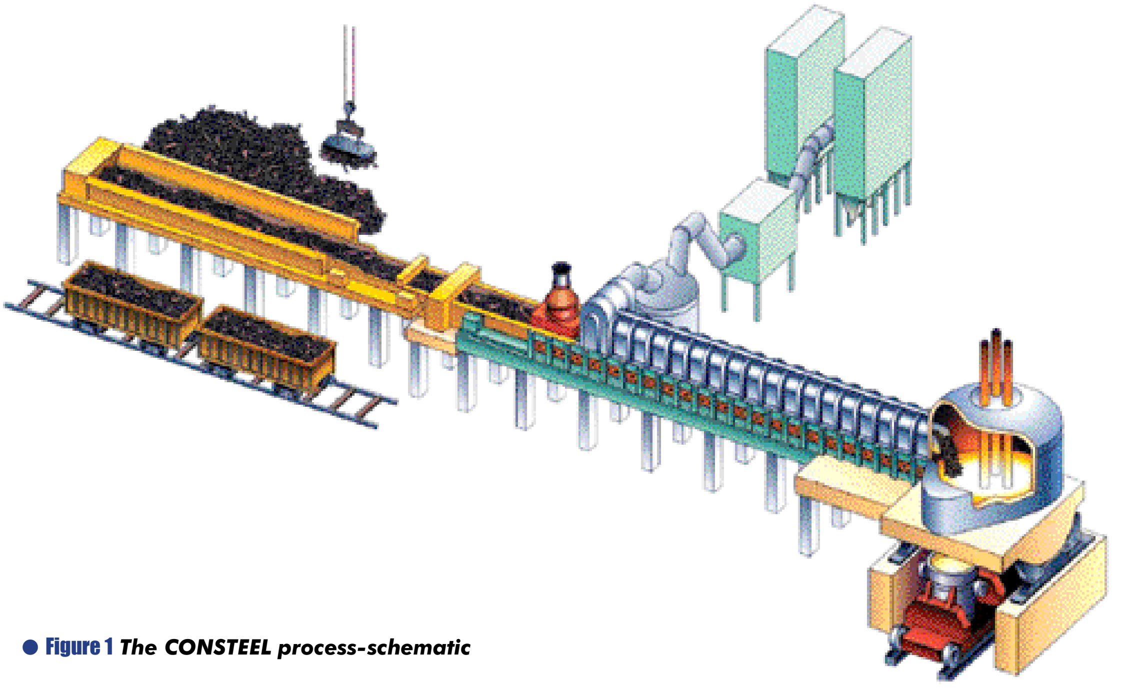
The CONSTEEL system was conceived with the objectives of reducing energy consumption and production costs, as well as improving the working environment through fume emission and noise reductions. The process (see *Figure 1*) is the only commercial technology that is able to continuously feed and preheat the metallic charge to the EAF while keeping the gaseous emissions under control, and without additional energy consumption. This pollution control technology meets the most stringent environmental regulations in Europe, Japan and USA.

The scrap is charged directly from the scrap yard, or from railroad wagons to the charge conveyor and is then automatically and continuously conveyed to the EAF by an enclosed preheating conveyor where the CO generated in the furnace from oxygen injection is progressively combusted by controlling the amount of air ingress. The post combustion of the CO, together with the sensible heat of the flue gases, preheats the metallic charge that is continuously conveyed to the EAF.

The fumes leave the preheater at high temperature and enter a secondary chamber where the gas is maintained at high temperature for more than two seconds to ensure the complete combustion of pollutants and thermal incineration of noxious emissions such as furans and dioxins. After this chamber, the fume gases are rapidly cooled to avoid any risk of dioxin reformation at low temperature and then enter a standard baghouse. There are presently 19 installations wordwide, as shown in *Table 1*.

Furnace off-gas pollutants

The main off-gas pollutants are VOCs, NOx, PAH,



● **Figure 1** ***The CONSTEEL process-schematic***

● **Table 1**
CONSTEEL installations

N°	Location	Customer	Size [t]	Power [MW]	AC/ DC	Start-up
1	Charlotte, North Carolina, USA	AmeriSteel Charlotte	41	24	AC	12/1989
2	Kyoei, Nagoya, Japan	Kyoei Steel	110	52	DC	10/1992
3	Darlington, South Carolina, USA	Nucor Steel	100	42	DC	09/1993
4	Sayreville, New Jersey, USA	Co-Steel New Jersey	80	40	AC	05/1994
5	Chonburi, Thailand	Nakornthai Strip Mill	180	95	AC	12/1997
6	Brescia, Italy	O.R.I. Martin	75	31	AC	08/1998
7	Xining, Qinghai Province, PRC	Xining Special Steel Group Co.	60	23	AC	01/2000
8	Guiyang, Guizhou Province, PRC	Guiyang Steel Mills	60	22	AC	06/2000
9	Hertford, North Carolina, USA	Nucor Steel	150	65	DC	07/2000
10	Knoxville, Tennessee, USA	AmeriSteel Knoxville	55	28	AC	07/2000
11	Shaoguan, Guandong Province, PRC	Shaoguan Iron & Steel Co.	90	60	AC	12/2000 (*)
12	Wuxi, Jiangsu Province, PRC	Wuxi Tristar Iron & Steel Co.	70	36	AC	09/2001 (*)
13	Shiheng, Feicheng, Shandong Province, PRC	Ji Nan Iron & Steel Co.	65	30	AC	02/2002 (*)
14	E'Cheng, Ezhou, Hubei Province, PRC	E'cheng Iron & Steel Co.	61	24	AC	08/2002 (*)
15	Tonghua Jiling Province, PRC	Tonghua Iron & Steel Group	65	34	AC	12/2003 (*)
16	Wei Chih, Tainan, Taiwan	Wei Chih Steel Industrial Co. Ltd	100	51	DC	UC
17	Hengly, Ninxia Province, PRC	Ninxia Hengly Co.	75	40	AC	UC (*)
18	Casablanca, Jorf Lasfar, Morocco	Sonasid	120	54	AC	UC
19	Wheeling, Ohio, USA	Wheeling Pittsburgh	320	102	AC	UC (*)

(*) Charges 70-75 scrap + 25-30% hot metal, UC means under construction

dioxins, furans, CO, CO_2 and dusts. These will now be described, together with how the CONSTEEL process deals with them.

VOCs, NOx and PAH VOCs are organic substances arising from raw materials and characterised by their bad smell. Both NOx and PAHs are polycyclic aromatic hydrocarbons. Each of these classes of compound contains a range of chemical species that are either in the liquid or vapour phases at typical off-gas temperatures, thus partitioning between the gas and dust phases occurs. Under conventional EAF charging conditions, large amounts of organic compounds are burnt off from the scrap when it is first charged. With CONSTEEL, off-gas flow composition and temperature are continuously monitored and the furnace draft is adjusted to make sure the VOCs do not escape to the shop and are safely burned in the preheater tunnel. In addition, any volatiles that evaporate from the scrap in the preheater tunnel are burned. Finally, the secondary combustion chamber at the end of the preheater section ensures complete combustion of all VOCs prior to gas cleaning.

NOx formation requires the break-up of the very stable nitrogen molecule at more than 1,100°C, followed by bond formation between the oxygen and atomic nitrogen in an oxidising environment. These conditions are favoured in the EAF due to the arc itself and if oxygen-gas or gas-air burners are not well regulated.

With CONSTEEL there are no burners and the process uses a foamy slag during the whole power-on time so that the arcs are covered. Moreover, progressive combustion of the CO over the length of the preheater leads to a non-oxidising flame for over two-thirds of its length; all conditions that favour low NOx levels.

There are more than 100 different compounds belonging to the PAH group, however, only a small number are commercially measureable. The main source of PAH emissions are the partial combustion (pyrolysis process) of oil and plastic materials. As PAHs are toxic, and the precursors for dioxin formation, they must be incinerated, and the secondary combustion chamber at the end of the preheater section ensures complete combustion prior to gas cleaning.

Dioxins and furans Polychlorinated dibenzo-p-dioxin (PCDD) and dibenzofurans (PCDF) are a group of chlorinated tri-cyclic aromatic compounds with related physical, chemical and biological properties. Different degrees and position of chlorination on the aromatic ring structures can occur leading to 75 PCDD and 135 PCDF isomers in total. In the environment, PCDDs and PCDFs are found in trace quantities as a mixture of these isomers, and are often referred to collectively as 'dioxins'. Some isomers of dioxin are among the most toxic chemicals known and may have carcinogenic and mutagenic effects.

There are three possible sources of PCDD/F emissions from combustion:

- PCDD/Fs present in the raw fuels being burnt
- PCDD/Fs formed via the condensation of chemically related compounds such as chlorobenzenes and chlorophenols found in the raw fuels (referred to as the precursor pathway)
- PCDD/Fs formed via *de novo* synthesis from chemically unrelated compounds such as cellulose, lignin, coal, polystyrene, polyvinyl chloride with inorganic chlorine donors (referred to as the *de novo* synthesis pathway)

Dioxin and furan control

The synthesis of PCDD/F structures requires certain carbon, oxygen, hydrogen and chlorine sources at a temperature of between 250°C and 450°C, an appropriate residence time and catalytic conditions. The cleaner the scrap charge, the less chloride is introduced into the system. Once formed, dioxins, furans and their intermediate organic compounds can be converted to CO_2 and H_2O by fully oxidising them at temperatures in excess of 850°C inside and/or outside the furnace, followed by appropriate cooling and gas-treatment practices.

With CONSTEEL, carbon is mostly combusted to CO_2 at the end of the preheater, where the off-gas temperature is kept in the range 1,000–1,100°C. The oxygen excess is in the range of 5-7% entering the post-combustion chamber where the residence time is more than two seconds. This condition assures the complete incineration of the dioxin. By maintaining a residence time of more than two seconds, and with the appropriate design for maximum turbulence, CO, H_2 and the organic compounds are fully combusted to CO_2 and H_2O. Once all the carbon is combusted to CO_2 (primary source for *de novo* synthesis of PCDD/Fs), the possibility of dioxin reformation is minimised. Also, in order to avoid any risk of dioxin reformation at low temperature an off-gas quenching system is employed.

Parameter	Traditional top-charged EAF	CONSTEEL EAF
Scrap-generated fumes suction	From primary circuit during melting/refining. From canopies (secondary suction) during charging	Always from primary circuit as the roof never opens
Temperature and oxidation control on secondary suction	No	No (not needed because of above condition)
Temperature and oxidation control on primary suction	No	Yes
Post-combustion chamber	Yes – water-cooled (it is acting as a sedimentation chamber, no burners)	Yes – refractory lined to maintain high temperature, no burners needed
Pressure control in EAF	Normally no	Yes, always

● **Table 2** ***Differences between a traditional EAF and a CONSTEEL EAF on gas suction***

CO

CO emissions are in compliance with worldwide requirements and are achieved by strictly and continuously controlling the temperature and oxygen level of the flue gases exiting the preheater and entering in the secondary combustion chamber.

Comparison of gas suction in conventional EAF and CONSTEEL

The main differences between a traditional EAF and CONSTEEL regarding gas suction are summarised in *Table 2*. With CONSTEEL, the furnace exhaust gas is continuously sucked through the preheater, which is the first part of the primary circuit. This means that, even when the furnace is tilted for tapping or deslagging, the openings in the furnace and the preheater are lined up, thus maintaining suction in the primary circuit. In the case of a batch-charged furnace, the secondary circuit

	Before CONSTEEL	With CONSTEEL	Before CONSTEEL [TOE/t]	With CONSTEEL [TOE/t]	Before CONSTEEL [tCO$_2$/t]	With CONSTEEL [tCO$_2$/t]
Electrical energy for melting	509 [kWh/t]	348 [kWh/t]	0.12	0.08	0.37	0.25
Oxygen	22.4 [Nm^3/t]	32.5[Nm^3/t]	0.002	0.003	0.016	0.023
Electrode	2.6 [kg/t]	1.4 [kg/t]	0.005	0.003	0.023	0.012
Natural gas	3 [Nm^3/t]	0 [Nm^3/t]	0.003	0	0.006	0
Carbon	6.3[kg/t]	9.1 [kg/t]	0.005	0.007	0.022	0.03
Electrical energy for gas suction plant	37 [kWh/t]	24 [kWh/t]	0.009	0.006	0.027	0.018
TOTAL [TEP][tCO$_2$]			0.14	0.10	0.46	0.34
Variation [%]			Base	- 30.0%	Base	- 27.3%

Key: TOE/t is equivalent tonnes of crude oil (TOE) consumption per tonne of steel tapped. tCO$_2$/t is tonnes of carbon dioxide (tCO$_2$) emitted per tonne of steel tapped

● **Table 3** ***Specific consumptions (per tonne of steel tapped)***

1kWh of electricity = 0.000734t CO$_2$
1Nm^3 of oxygen = 0.0007t CO$_2$
1 TOE of electrode or carbon = 4.52t CO$_2$
1 TOE of natural gas = 2.35t CO$_2$
1kWh of electricity = 0.00023 TOE
1Nm^3 of oxygen = 0.00008 TOE
1kg of electrodes = 0.00193 TOE
1Nm^3 of natural gas = 0.00082 TOE
1kg of carbon = 0.00075 TOE

● **Table 4** ***Conversion factors***

(canopies) suction must be used during tapping and charging because the primary suction has to be interrupted. A large quantity of gas has to be processed because of the ambient air that is collected, together with the furnace gas. At the same time, the use of the primary suction circuit reduces the quantity of dust that is released in the area surrounding the furnace. It has been shown in other studies that most organic pollutant compounds are released when the suction is performed by the canopies.

The higher temperatures in the primary circuit are useful in destroying this type of pollutant, thus CONSTEEL has a double advantage in that not only is suction always performed by the primary circuit, but also, the preheater cover and sedimentation chamber are refractory lined to keep the gas temperature as high as possible.

Preheating

The scrap temperature increase in the preheater is often cited as a cause for gaseous organic compound generation, however, this is no different to the temperature increase in the EAF where the scrap is heated up by the gases and the arc. With CONSTEEL scrap is preheated for 5–10 minutes just prior to the scrap falling into the liquid bath at 1,600°C. The automation system makes sure that enough oxygen is supplied for post-combustion of gas.

Global warming and the need to reduce CO$_2$ emissions

The greenhouse effect and global warming are issues that have been receiving increased media attention, particularly since the 1997 Kyoto conference on climate change. The Kyoto Protocol aims to achieve a significant reduction in CO$_2$ emissions from non-natural sources, which are believed to be one of the main causes of global warming. The Protocol's goals vary according to economic region (for the EU, for instance, they call for an 8% cut in 1990 CO$_2$ levels by 2010).

On the above basis the pollution from an industrial process should be evaluated as the total amount of pollutants generated by energy production and/or the material utilised during the process itself. In calculating the overall consumption of energy in the melting process, it is necessary to take into account both the energy used directly in the furnace and the energy used indirectly to produce such consumable items such as electrodes.

Table 3 compares performances of the CONSTEEL system at the ORI Martin plant, Italy, one year after start-up, with that of the old melting unit that it replaced. The data are taken from a study made by an independent engineering company and based on ORI Martin's heat reports.

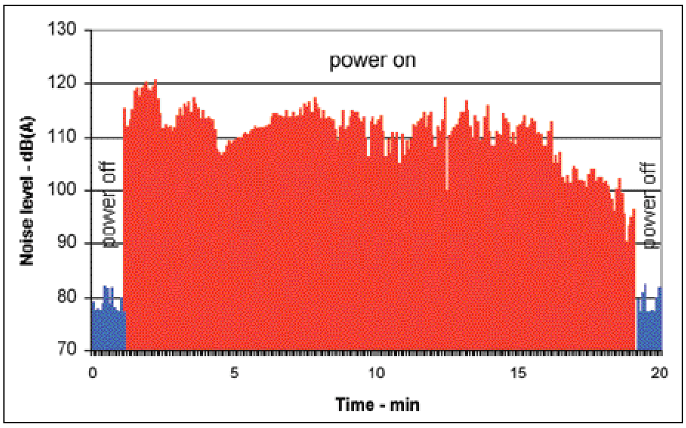
The overall consumption of fossil fuels and the related emissions of carbon dioxide are significantly reduced by the new melting technology. The data are calculated based on conversion factors used by European organisations (the conversion values are given in *Table 4*). *Table 3* indicates a reduction in emission of carbon dioxide of approximately 27%.

EAF dusts

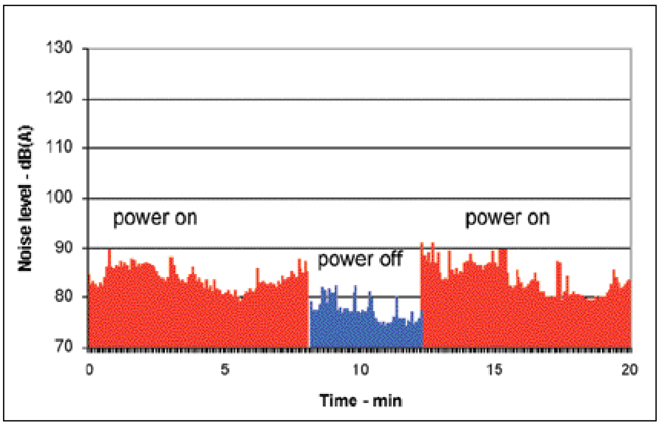
In the CONSTEEL process, dust settles on the scrap due to the low velocity of the waste gas inside the preheater, so less dust escapes and less dust reaches the baghouse bags, resulting in more efficient filtering and hence less dust to dispose of. At its best a 30% reduction is obtained. Since the furnace roof is not usually opened during operations and the furnace itself is under a slight negative pressure, there is no release of dust into the working area.

Other EAF pollutants

Noise The low noise levels with CONSTEEL result from the use of a foamy slag practice which covers



● **Figure 2** ***Noise levels during melting – EAF***



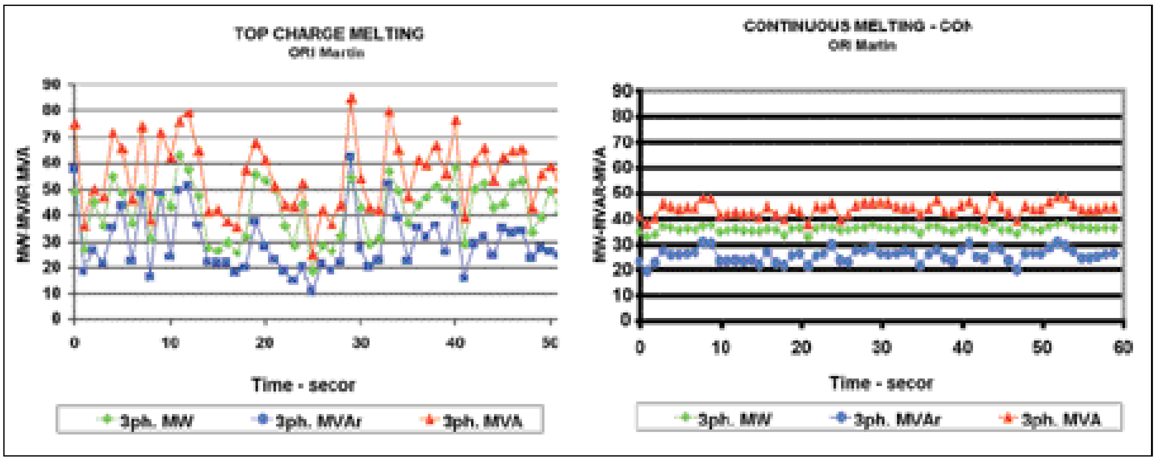
● **Figure 3** ***Noise levels during melting – CONSTEEL***

the arcs. *Figures 2* and *3* compare the noise levels during power-on before and after installation of CONSTEEL at ORI Martin. A reduction from 110 to 85-90dB(A) is seen. The noise level is always below 95dBA 10m away from the slag door and the average during melting is below 90dBA.

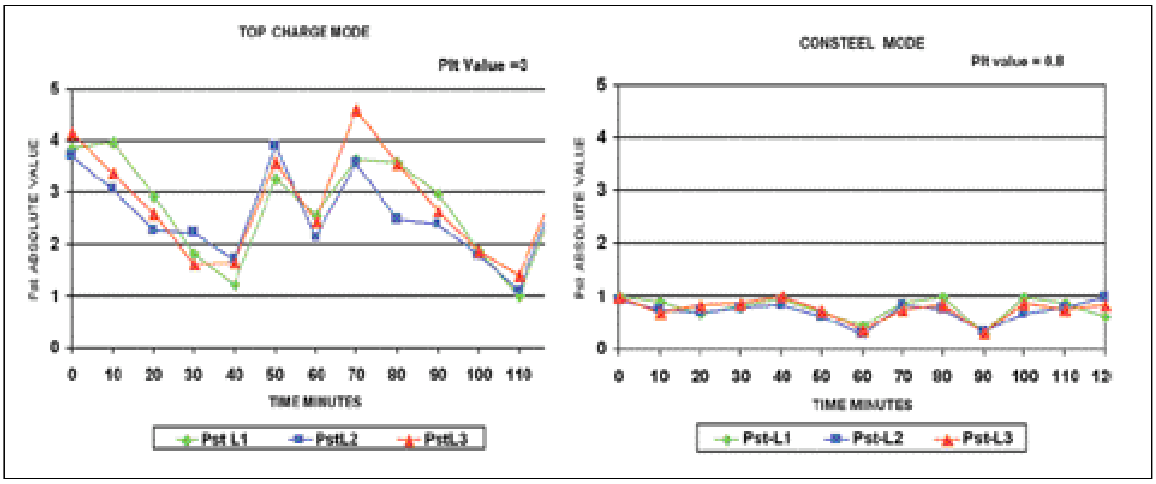
Radioactivity Charge materials are normally checked for radioactivity at the plant entrance. This control is very important because, apart from preventing radioactive material from entering the plant, it enables the supplier of the contaminated material to be identified. Additionally, after the charge materials have been loaded onto the conveying system, and before they enter the preheating tunnel, the materials pass over a second radiation detector located underneath the conveyor. This is more accurate than monitoring scrap in trucks or buckets and if abnormal radiation is detected, the feeding operation is automatically stopped before the scrap reaches the furnace, and the operator is warned of the potential danger.

Power network disturbances With CONSTEEL, flicker and harmonics are typically reduced by 60–70% when compared to the batch-charged furnace, again due to the foamy slag practice. Some trials were made on the ORI Martin plant where the electricity supplied to the transformer is fed by two parallel-connected 40MVA-substation transformers (130/11kV). Measurements were made on the primary and secondary sides of the 130/11kV network to determine the electrical characteristics of the load pattern, voltage flicker and harmonic current distortion. The apparent, active and reactive power levels were monitored on the 11kV line in order to record the load characteristics. *Figure 4* clearly shows the very stable load characteristics of the process.

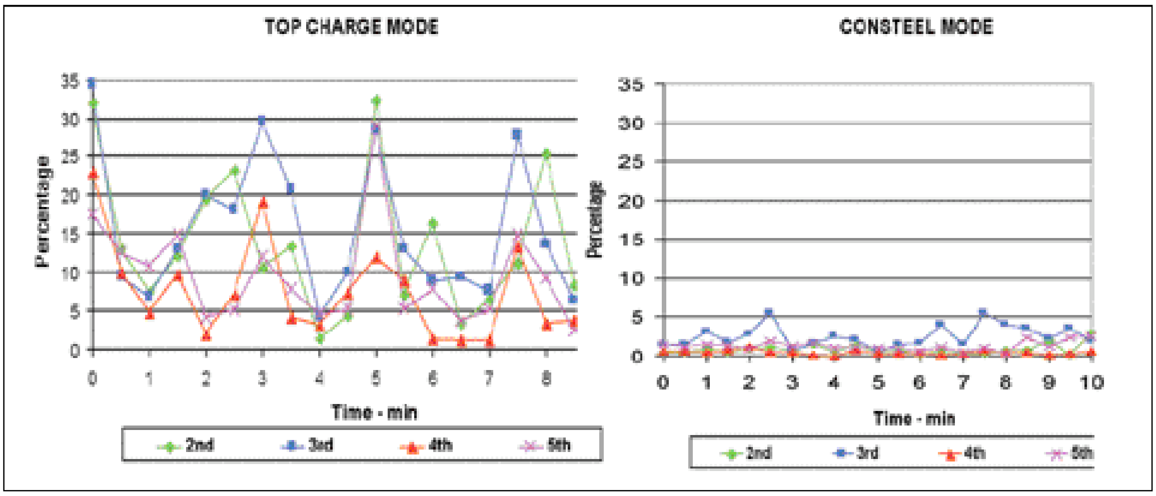
Flicker generated by both modes of operation were measured on the 130kV coupling point of the plant (short circuit capacity = 2,500MVA). *Figure 5* compares the trend in short-term flicker (PST). With CONSTEEL none of the three phases exceed a PST value of 1. The calculation of the related long-term value (PLT) leads to a value of 0.8. Measurements of current harmonics (second, third, fourth and fifth) on the 11kV line have also been recorded (see *Figure 6*),



● **Figure 4** ***Electrical characteristics***



● **Figure 5** ***Short-term flicker (PST) on the electricity supply network***



● **Figure 6** ***Harmonics currents on the electricity supply network***

indicating lower values by a factor of at least four than those in the batch, top-charged furnace. Thus, the impact of the CONSTEEL process on the power-supply network is very low and already complies with the limits that will be set by the European Community in future years.

Moreover, with the CONSTEEL system, the installation of a SVC (static compensator of the reactive power) is not needed.

Conclusions

Over the past few decades the iron and steel industry has been placed under considerable pressure to dramatically reduce the level of emissions for greater environmental protection.

The CONSTEEL process has been installed in Japan, Europe and USA where the pollution limits are already very strict and stack emissions comply with their environmental regulations without the need of special gas treatment such as post-combustion burners or injection of adsorbents. With regard to other pollution sources such as noise, radioactivity and electrical noise, the CONSTEEL process is helpful, both in minimising them and in reducing plant costs by avoiding the installation of equipment such as SVC and doghouses. The combination of low consumption of energy and consumables with a low emission of CO_2 makes CONSTEEL a steelmaking system that both reduces production costs and environmental impact.

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