De-dusting plants for electric arc furnaces

The efficient cleaning of EAF off-gas by a combination of post combustion of the primary off-gas, fast cooling in a quenching tower and use of dioxin absorbents prior to dust filtering, enables the dioxin concentrations in the waste gases to be reduced below statutory limits.

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The pollutants produced by the EAF process: dust (heavy metal oxides), and gaseous compounds (CO, nitrous oxides [NOx], volatile organic compounds, [VOC]) and dioxins and furans, pose environmental problems, so efficient methods to reduce these emissions are essential. EAF de-dusting plants normally comprise a primary off-gas line, which receives the emissions directly from the furnace cover, and a secondary off-gas line, which collects all other emissions, eg, produced during charging and tapping casting. With this approach it is possible to achieve dust removal efficiencies of 95–99% over the casting cycle.

CONTROL OF OFF-GAS

The heart of the de-dusting plant is the filter. The two main types in use (for economic and environmental reasons) are: a fabric filter with a compressed air cleaning system (pulse-jet filter, mostly used in Europe), and a reverse air cleaning system (bag-house, mostly used in North America).

A typical de-dusting plant configuration is shown in *Figure 1*:

- The primary off-gas (~1,600°C) is extracted directly from the EAF roofcover **[1]** and collected by the water-cooled elbow of the exhausting flue
- A fixed duct separated from the furnace, sometimes equipped with a mobile end in order to permit the opening of the furnace roofcover **[2]**, is situated in front of the elbow when the furnace is in the horizontal position for melting/refining, and collects and blends the gas coming out from the elbow with the ambient air sucked through the gap between the two ducts. The function of this additional suction is to introduce a quantity of oxygen sufficient to burn the entire CO still present and to cool down the gas.
- The absorbed off-gas enters the post-combustion chamber or drop-out box **[3]** (so-called because separation of the larger particles occurs here in order to avoid undesired sediments along the pipelines after the chamber)

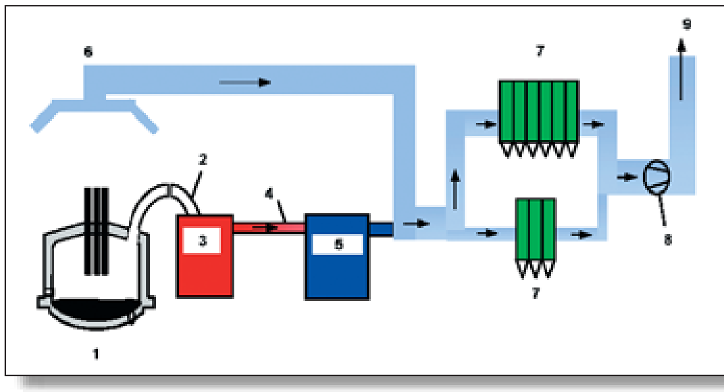

Fig.1 Typical off-gas treatment plant for EAF

- Next, the hot off-gas enters the water cooling duct (WCD) **[4]**, which cools it to 500–800°C, depending on the length of the duct
- After leaving the WCD, the hot gas is further cooled to 200–300°C **[5]** by a forced draught gas cooler (FDC), a natural draught cooler (NDC) or a quenching tower (QT). The lower limit of this temperature range is imposed by economic reasons, because the cost of any cooler increases exponentially below 200°C.
- The direct evacuation control damper, which is usually situated after the cooling system, controls the quantity of gas extracted from the EAF in order to avoid excessive heat absorption from the furnace during those phases where the generation of gas is limited.
- The primary gas at 200–300°C is then blended with secondary gas at 50–70°C coming from the canopy hood **[6]** situated over the furnace, to reach temperatures below 130°C, suitable for gas filtration in a fabric (polyester bag) filter **[7]**.

PRIMARY DE-DUSTING

The primary de-dusting line absorbs most of the emissions during operations with the EAF roof closed. Its efficiency is directly related to the pressure drop in the furnace, and is maintained by the de-dusting plant. Nevertheless its efficiency is limited by unexpected pressure increases in the furnace, due principally to sliding of the scrap, ▷

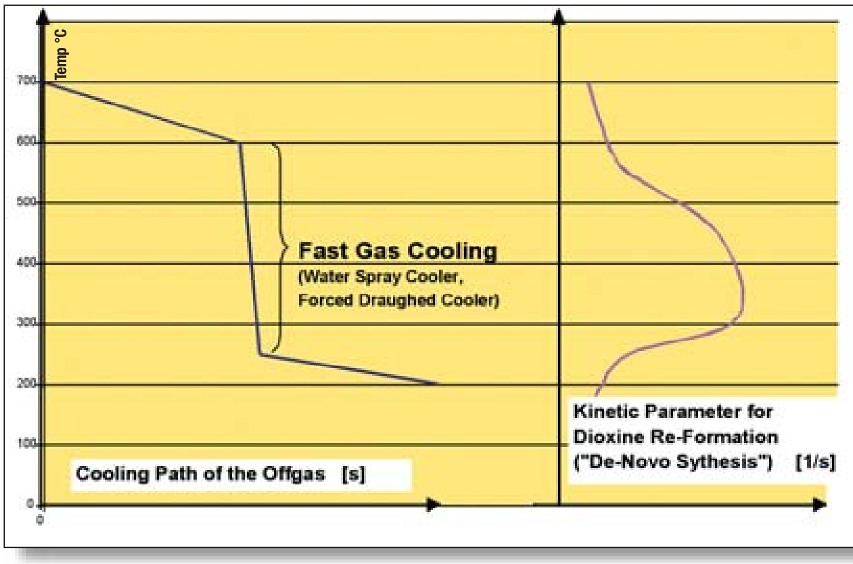

Fig.2 Temperature path and dioxin reaction velocity

reactions in the bath or addition of additives. For this reason it is necessary that fume extraction via the secondary canopy hood of the furnace is maintained.

SECONDARY DE-DUSTING

The secondary de-dusting line absorbs the emissions coming from the canopy hoods situated over the furnace, which can have one or more suction points inside a bigger hood for more homogeneous suction. The correct sizing of a canopy hood is based on the geometry of the shaft and fluid mechanics of the off-gas passing into the canopy hood. Even if correctly dimensioned, the efficiency of secondary de-dusting can be considerably influenced by the presence of horizontal air movements, due to opening of the building, other warm air sources present in the building, or the presence of the charging crane. For this reason the correct sizing of a secondary canopy hood is increasingly performed by fluid dynamics computer simulation programs, but a guarantee of 100% collection is unlikely except by unreasonable and uneconomic over-sizing of the de-dusting plant.

An alternative approach is to use an elephant house: a total closure that isolates the furnace building and evacuates the emissions through a cowl situated on the roof. For this reason the openings of the building should be sealed and the entire furnace module totally enclosed during all the process phases. Also, the sliding doors for scrap charging must be opened only for the time strictly necessary for this operation. In this case the capacity of the canopy must be sized in order to ensure not only the suction of the fumes emitted during charging and tapping, but also sufficient air exchange inside the module to maintain working conditions. This normally means the design of a plant with the same maximum capacity of a normal plant, but with a higher average capacity.

DIOXIN

Of the various pollutants generated during metallurgical processes, dioxin is one of the most dangerous. Dioxin is a generic word for a combination of 75 PCDDs (polychlorinated dibenzo-p-dioxins) and 135 PCDFs (polychlorinated dibenzo furans). The problem of dioxin emissions is critical generally in EAF steelmaking processes, but the problem becomes more relevant in furnaces with scrap pre-heating. VAIM has studied dioxin generation processes and reduction techniques for the off-gas. These studies show that the concentration of dioxin in the primary off-gas stream is about 10 times higher than in the secondary off-gas stream, despite the fact that the primary stream comes directly from the combustion area where dioxins should be destroyed at high temperatures. These high concentrations arise because during the primary gas cooling phase, dioxin re-forms as a result of the reaction between the organic and chlorine compounds at temperatures between 280 and 600°C. This process is called De novo Synthesis and has a maximum productivity in the range 300–500°C (see *Figure 2*). For this reason it is common to find high dioxin concentrations in the cooled primary off-gas. Quantitatively, the phenomenon is proportional to the duration of this condition, hence the speed of cooling is extremely important.

COOLING OF PRIMARY OFF-GAS

The cooling of the primary off-gas can be performed in different ways, of which the principal ones are the FDC and the QT:

The forced draught gas cooler The most common types of FDC used in EAF de-dusting plants are the Tubular heat exchanger and the Cross-stream Tube/pocket heat exchanger. The second type is of interest because of the reduction in maintenance costs compared to a traditional tubular type design. In the primary de-dusting plant the cooler is typically situated after the WCD. The cooler can cool off-gas from temperatures of around 550–600°C down to around 200–300°C. The cooler inlet gas temperature is strongly limited by the material property, in this case Corten or 16Mo3.

The tube/pocket heat exchanger functions by cooling the hot inlet gas in one or two passages. Ambient air is forced through the tubes in order to assist convection currents to remove the heat from the gas. The name of this exchanger results from the 90° angle in which the direction of flow of the two streams (hot and cooler one) cross each other. The cooling air is forced to flow through the tubes/pockets by using fans installed on the side of the cooler.

Quenching towers Dioxin regeneration can be minimised by cooling the gas very quickly, in order to

Pollutants		Concentrations		Flow	
		Measured values	Limit values	Calculated values	Limit values
Dust	(mg/Nm^3)	4.6	5	2.8 (kg/h)	3(kg/h)
O_2	%	20.3	-	-	-
CO_2	%	0.5	-	-	-
CO	(mg/Nm^3)	80	200	58.7 (kg/h)	
SO_2	(mg/Nm^3)	<3	-	<2.2	-
NO_2	(mg/Nm^3)	12	-	8.8	-
NOx *	(mg/Nm^3)	16	100	11.7 (kg/h)	20 (kg/h)
VOC total **	(mg/Nm^3)	2	-	1.47 (kg/h)	-
VOC nm **	(mg/Nm^3)	1	-	0.73 (kg/h)	-
HCl	(mg/Nm^3)	0.2	-	146.8 (kg/h)	-
HF	(mg/Nm^3)	0.2	-	146.8 (kg/h)	-
Metals					
Group 1 (1)	(mg/Nm^3)	0.12	0.15	68.8 (g/h)	75 (g/h)
Aggregate 2 (2)	(mg/Nm^3)	0.003	0.1	2.2 (g/h)	9 (g/h)
Aggregate 3 (3)	(mg/Nm^3)	<LD	1.0	<LD	40 (g/h)
Aggregate 4 (4)	(mg/Nm^3)	1.136	5.0	834 (g/h)	400
Fe	(mg/Nm^3)	1.67	-	1226 (g/h)	-
Ti	(mg/Nm^3)	0.003	-	146.8 (g/h)	-
PCDD/PCDF	(pg/Nm^3)	73	500	0.054 (mg/h)	0.25

* expressed in equivalents of NO_2
** expressed in equivalents of C
(1): Pb particulates + gas
(2): Cd+Hg+Ti particulates + gas
(3): As+Se+Te particulates + gas
(4): Sb, Cr, Co, Cu, Sn, Mn, Ni, V, Zn particulates + gas

Table 1 Dedusting efficiency data using pulse jet and QT

reduce the time it remains at the temperatures for De novo synthesis. This chemical-physical principle is optimised in the QT, which provides rapid cooling of the primary off-gas by water quenching with fine atomised sprays, so that the gas temperatures decrease rapidly to 250–280°C. In the most common type of quenching tower used by Decos (VAI Group Technological Center of Competence for EAF dedusting) for EAF de-dusting plants (3.2–6m diameter and 10–15m high), the hot gas enters the QT at the bottom (see *Figure 3*) through a large central box, in which the gas velocity is reduced and the flow is equalised. After the inlet, the off-gas is then immediately cooled by the evaporation of the atomised water that is injected by means of lances in the lower part of the tower. The cooled and dry off-gas exits from the upper part the QT, blended with the cooler secondary off-gases then filtered in a pulse-jet filter. Dioxin distribution using QT is shown in *Figure 4*.

Because of its efficiency the quenching tower is the preferred primary gas cooling system for both new and revamped plants. The change from an FDC to a QT can be executed without major changes to the complete de-dusting system and the performance improvements are excellent. Optimisation of the QT has meant several plant improvements that ensure the off-gas inlet QT temperature is more than 600°C and the setting up of an automatic regulation of the cooling water injection is stable (see *Figure 5*).

Fig.3 Quenching tower

Lignite injection Although the performance of the quenching tower is good, it is difficult to guarantee the achievement dioxin maxima of 0.1ng/Nm^3 continuously. Further improvements can be obtained by injecting ▷

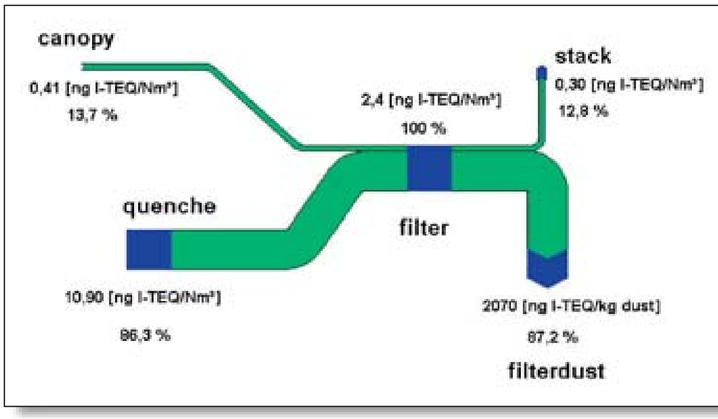

Fig.4 **Dioxin distribution using QT**

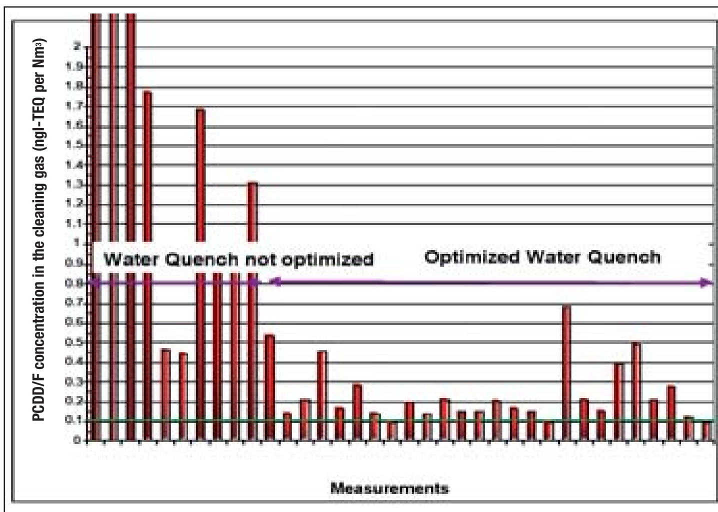

Fig.5 **Dioxin measurements pre and post quench optimisation**

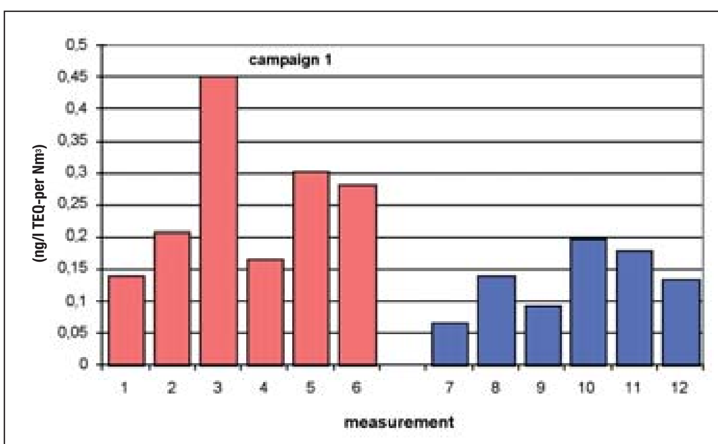

Fig.6 **Concentration of dust emitted in atmosphere, blue using QT with absorbents injection, red without absorbents injection**

absorbents into the gas stream, before the filter which aggregate to bigger and more easily filterable dust particles (see *Figure 6*). The injected material is porous, very finely milled lignite coke, in order to get a high surface-volume ratio to promote dioxin precipitation. Injection is via nozzles before the filter and after the cyclone, typically between 150 and 500 mg/Nm3.

It can be seen from *Figure 7* that the tendency of dioxin

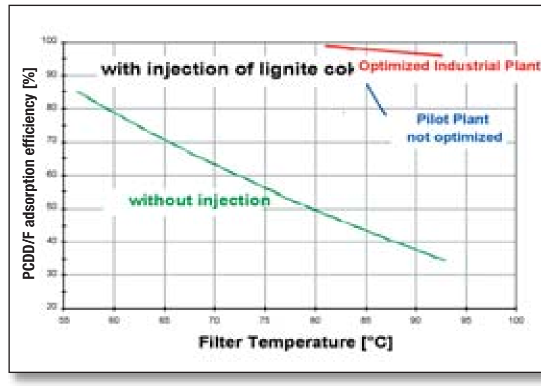

Fig.7 **Dioxin absorption efficiency as a function of filter temperature and absorbent injection**

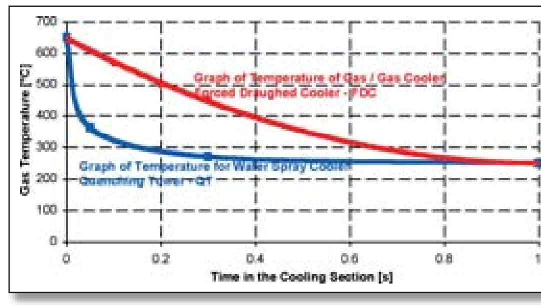

Fig.8 **Gas temperature vs time in an FDC and QT**

removal is directly proportional to the decrease in the off-gas filter inlet temperature. In order to reach the desired dioxin removal levels, it would be necessary to have a filter inlet temperature of less than 80°C if a lignite injection system is not used. For traditional furnaces, the dioxin value present in off-gases reachable with this system is about 0.1ng/Nm3.

COMPARISON OF FDC AND QT

Although the time of residence of the hot gas in both systems is approximately the same (FDC: gas velocity around 20m/s, length 25m, therefore t = 1.25s, QT: gas velocity around 8m/s, length 10m, therefore t = 1.25s), the cooling curves are completely different (see *Figure 8*). The QT, by using fast cooling, is much more efficient in reducing dioxin regeneration. This has been demonstrated by PCDD/F measurements at a plant where the original FDC has been substituted by a QT.

The quenching tower is not the only system to achieve low dioxin values, but it is important to note that faster cooling reduces the quantity of dioxin in the off-gases prior to the filter, thus the amount of carbon (lignite) required for injection is significantly lower than in a plant with FDC. A further advantage is that existing plants equipped with FDC can be easily revamped, with additional advantages of increased primary suction capacity and often with a reduction of the space required (see *Figure 9*). This suction capacity increase in the primary side of the de-dusting system is achieved without changing the main fans.

Also, as the maximum inlet temperature of a QT is 1,000°C, versus 600°C in an FDC, this results in a shorter

Ⓐ **Fig.9 Substitution of an FDC (a) by a QT (b) in an existing installation**

primary WCD and greater flexibility in the plant design and installation. The maintenance on the QT is usually lower (systematic check and cleaning of the lance nozzles) compared to an FDC, which has a tendency for the ducts or pockets to clog.

POLLUTANT REMOVAL EFFICIENCY

In modern EAF off-gas systems it is possible to achieve a dust concentration of less than $5mg/Nm^3$ in the atmospheric emissions with a fabric pulse-jet filter. A further reduction of this dust concentration will not significantly reduce the dioxin content of the cleaned gas. Significant improvements in dioxin removal can be achieved by injecting absorbent material as well as decreasing the off-gas filter inlet temperature.

The efficiencies achieved by modern de-dusting plants are shown in *Table 1* from a recent analysis of a VAIM-DECOS installation, in which a pulse-jet filter and a QT were utilised. This plant operates a 70t furnace, with a productivity of 100t/h.

CONCLUSIONS

For the efficient cleaning of EAF off-gas, a combination of thermal treatment, as post combustion of the primary off-gas, fast cooling in a quenching tower, and absorbent-injection, enables the dioxin concentration to be reduced to levels below the specified limits. The technology for minimising the dioxin present in off-gas described in this paper is the most efficient and economic solution and features the latest state of the art technology. MS

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