ISSN 0543-5846
METABK 41 (3) 165 (2002)
UDC - UDK 669.18.013.5:628.5=20

ENVIRONMENTAL CONTROL IN INTEGRATED STEELWORKS

Received - Primljeno: 2001-12-09
Accepted - Prihvaćeno: 2002-03-15
Review Paper - Pregledni rad

The paper deals with Integrated Prevention and Pollution Controll (IPPC) directive and its application in steelmaking industry. The Best Available Techniques (BAT) principle is defined as the one of the most important tools of IPPC. Next four fundamental iron and steelmaking processes are discussed from the point of view of specific pollution to environment: production of iron ore sinter, production of pig iron in blast furnace, basic oxygen steelmaking, electric arc steelmaking, and BATs for the proccsses are defined.

Key words: *environmental control, integrated steelworks, best available techniques (BAT)*

Konrola okoliša u integriranim čeličanama. Rad se bavi direktivom o prevenciji i kontroli zagađivanja u integriranim čeličanama (IPPC) i njenom primjenom u industriji čelika. Načelo najbolje raspoložive tehnike (BAT) definirano je kao jedan od najvažnijih alata IPPC-a. O slijedeća četiri osnovna procesa za dobivanje željeza i čelika raspravlja se sa stajališta posebnog zagađivanja okoliša pa su tako definirane i proizvodnja sinterovane željezne rude, proizvodnja sirovog željeza u visokim pećima, proizvodnja čelika u konvertorima, proizvodnja čelika u elektrolučnoj peći i BAT za provođenje procesa.

Ključne riječi: *kontrola okoliša, integrirana čeličana, najbolja raspoloživa tehnika (BAT)*

INTRODUCTION

The fundamental motto of the modern steelmakers all over the world has been transformed to the declaration: “Steelmaking industry will continue in seeking the ways of improving the energetic efficiency of the processes, the ways of the environmental pollution decreasing and the ways of decreasing the costs related to consumption of raw materials and energy inputs”.

To promote this approach, that concerned also the other industrial technologies, the world community was forced to create new obligatory legal documents with direct influence on economy of the individual country. Current state accepts the individual approaches of the countries that are drawing to unify common principles.

In Europe, exactly in the European Union countries, the „Integrated Prevention and Pollution Control (IPPC)“ directive expressed these principles. IPPC directive comes in to force in October 1999.

New and modified processes require regulation under IPPC from 1 November 1999. Regulation for other existing processes will be put into force by the end of 2007.

Ľ. Mihok, Faculty of Metallurgy, Technical University of Košice, G. Lešinský, U. S. Steel Košice, Košice, Slovakia

IPPC DIRECTIVE - NEW TYPE OF LEGAL TOOL OF EU

IPPC belongs to a very new type of legislation tools; it moves the solving of environmental problems to their sources. It changes also the current strategy of checking and control of emission limits through so-called end technologies - flue dust filtration, dumping sites, etc. Modern strategy of environment protection, supported by such a tool as the IPPC, is directed to so called “Cleaner Production”, implemented to production technologies. It deals with prevention of waste generation concerning decreasing of the production costs.

It is important to point to the general principles of IPPC; installations shall be operated in such a way that:

- all appropriate preventive measures against pollution must be taken, in particular through the application of Best Available Techniques (BAT);
- no significiant pollution shall be caused;
- waste production is avoided (the waste management hierarchy should be followed in accordance with the Waste Framework Directive);
- energy is used efficiently;
- necessary measures are taken upon the cessation of activities to avoid pollution risk and to return the site of operation to a satisfactory state.

IPPC directive is covering pollution (contamination) of air, water, soil and countryside by emissions, generation of wastes and waste treatment processes, consumption of energy and raw materials, accidents and local contamination. Emissions are in form of gaseous and particulate matters, heat, noise and vibrations.

IPPC directive covers six principal categories of the industrial production:
- energetic industry;
- production and treatment of metals;
- treatment of mineral sources;
- chemical industry;
- waste treatment;
- other (production of cellulose and paper, some food and agricultural activities).

The purpose of the IPPC directive establishment and its implementation to the legal systems is to achieve integrated prevention and control of pollution arising from above mentioned range of activities. It lays down measures to prevent or to reduce pollution in air, water, as well as on land from above mentioned activities, including measures on waste treatment and waste production, in order to achieve a high level of protection of the environment as a whole.

In addition, IPPC directive introduces an integrated permitting system, which is required for listed activities and which must contain specific conditions including emission limit values and the application of BAT.

BAT PRINCIPLE

The directive deals and concerns only with sizeable industrial complexes and enterprises. With exception of chemical industry, it doesn't solve the problems of small and medium factories.

One of the most important issues of the IPPC is application of the BAT principle. Its main goal is to produce unambiguous basis for specific conditions including emission limits as Emission Limit Values (ELV). Obligatory exchange of information concerning the BAT principle, the BAT Reference Document (the BREF document), is also included.

The BAT descriptions contain mainly:
- characteristics of the process technology;
- specific production of emissions, waste and by-product generation, needs and consumptions of raw material and energy inputs;
- the most effective technologies related to decreasing of emissions and wastes rates and to increasing of energy savings;
- identification of BAT technologies,
- the new and developed technologies and processes.

SPECIFIC POLLUTION OF METALLURGICAL PROCESSES TO ENVIRONMENT

Production of Iron Ore Sinter

To each one metric ton of iron ore sinter following amount of contaminants and wastes is produced.

Air pollution (kg/t of sinter): 20 kg CO,
150 kg CO_2,
1.5 kg SO_2,
0.6 kg NO_x,
0.2 kg PM,
0.5 kg of the fine dust.

For each ton of sinter production an amount of 250 kg of sinter comes back to the process as returned sinter.

Specific contaminants of the sintering process are: dioxins/furans (PCCD/F); Pb; Cd; Zn; Ni; Cr; alkalies; radioactive isotopes (210 Po, 210 Pb); volatile organic substances; hydrocarbonates; solid contaminants; HCl; HF. Specific contamination of off-gases is directly related to composition of the sinter charge and directly connected to the specific technology condition of the sintering process.

Air pollution by sintering process

Sintering plant is normally equipped with two cleaning systems of off-gases – the first one is used for the primary flue gases from the sintering processes cleaning; the second one is used for the dusts exhausting and dedusting by material and product handling and sizing.

Some sintering plants use for filtration of primary flue gases a dry multicyclone or wet scrubbing system. As the dry cyclone is not sufficiently efficient and wet scrubbing can produce the water pollution, new and upgraded installations are often equipped by electrostatic precipitators (ESP) as the means of flue gas treatment. Most recent development in some sinter plants led to the use of wet scrubbers or bag filters as the post - ESP facility. New types of ESP are able in the last ESP field to select coarse dust particles from the fine ones containing bigger part of heavy metals. Some problems of ESP operation can be connected to sinter charge basicity, low dew point of off gases, high exhaust gas temperature particularly by cooling of sinter product, and other.

Recycling of mill scales with oil content, namely mill scale sludge with 20% or more of oil can be detrimental to ESP performance. The particles with oil can form deposits on ESP electrodes resulting in "glow fires" and, possibly, in ESP break - down. The deposits should be analysed periodically for the oily matters (hydrocarbon matters) contents and additions of oily mill scale into the sinter charge should be closely controlled.

Some developments lead to the return of proportion of off-gases from sinter cooling to the sinter strand ignition hood. It results in reduction of dust emission and reduction of amounts of NO_x gases released to atmosphere and from fuel consumption point of view the reason is to use it for sensible heat recovery.

The sensible heat recovery from other cleaning systems - mainly from sinter coolers, sinter crushing and sorting equipments - are very often used by upgrading of installations.

BAT technologies for iron ore sinter production (according to IPPC)

1. Primary flue gases from sintering process de-dusting.
2. Off-gases from sinter cooling de-dusting.
3. Sensible heat recovery at the sintering process (entire surface of the sinter strand) and from sinter cooling processes.
4. PCDD/F emissions (dioxines, and furanes) by waste gases recirculating minimalisation.
5. Heavy metals emission by wet scrubing system application or exclusion of dusts captured in the last field of ESP minimalisation.
6. Waste generation minimalisation.
7. Primary off-gases hydrocarbon content by fuel quality of the sinter feed changing minimalisation.
8. Waste heat recovery.
9. SO_2 emission by lowering of sulphur input or by waste gas desulphurisation minimalisation.
10. NO_x emissions by waste gas recirculating or by denitrification minimalisation.
11. Contamination of water minimalisation (relevant only in the case when wet waste gas treatment is used; cooling water can be used).

Pig Iron in a Blast Furnace Production

To each ton of pig iron produced in BF following harmful contaminants, wastes and other by-products are released.

As an air pollutants (g/t of p. i.):
- 500 - 1000 g CO;
- 400 - 900 g CO_2;
- 100 - 400 g SO_2;
- 50 - 550 g NO_x;
- 30 - 85 g particulate matter (PM);
- 0.001 - 0.004 μg I-TEQ/Nm^3 PCCD/F.

As a water pollutant (g/m^3):
- 10 g of suspended matters;
- 20 g of oil;
- 1 g of cyanides;
- 2 g of soluble metals;
- total production of waste water 0.2 m^3 /pig iron.

Production of wastes and secondary raw materials (kg/t of hot metal):
- 250 - 350 kg of blast furnace slag;
- 10 - 20 kg of dusts from dry BF gas cleaning;
- 5 - 30 kg of sludges from wet BF gas cleaning;
- 2 - 5 MJ/t of BF gas;
- 0.5 - 1.5 kg/t p.i. dust from secondary dedusting;
- 0.1 - 3.0 kg/t pig iron of rubble.

Specific contamination by BF slag processing:
- particulate matter;
- 0.2 - 20 g/t of pig iron of H_2S.

Air pollution by pig iron production

The BF top gas (BF-gas) contains particulate matter (fine particles in compliance of BF burden, iron oxides, fine particles of primary slag, Zn and Pb oxides, alkalis), carbon monoxide and carbon dioxide, nitrogen, hydrogen, zinc and lead vapours, sulphur compounds, ammonia, cyanide compounds, hydrocarbons and polycyclic aromatic hydrocarbons compounds.

BF-gas is a very valuable energy source (the heating value is in range of 3.0 - 3.8 MJ/Nm^3), which can be effective utilized in many applications in integrated steelworks. Whole volume of BF-gas is captured, cleaned and utilized; the generation of BF gas is approximately 1200 - 2500 Nm^3/t of pig iron; no significant releases of the BF-gas into air (small amount in connection to equalizing of BF gas pressure at the top of blast furnace by charging) are recorded.

The BF-gas is treated in two steps. The first one is in dust catcher, where coarse dust originating mainly from the charge fines, is captured. The second step is realised in multistage wet scrubbing treatment systems, which remove fine dust particles containing also alkali metal chlorides, heavy metals and polycyclic aromatic hydrocarbons. Some blast furnaces are equipped also with electrostatic precipitators.

Secondary emissions to air mainly come from foundry operations and there are basicaly particulate matter and Fe oxides forms in them. Around and above a tap hole there is increased concentration of CO, CO_2 and a heavy metals vapour especially in time of hot metal tapping. These secondary emissions can be effectively controlled by local exhausting systems at the tapping and ladle or torpedo charging points. The methods of inert gas (nitrogen, CO_2, natural gas etc.) as blanketing systems around tapping hole, runners and ladle or torpedo charging points were described.

Water pollution

Blast furnace shell body together with tuyeres and some other equipment are cooled by one or a number of closed cooling water systems. This system needs only small additions of new technical water in pre-determined intervals. The cooling water is contaminated with dust deposits on the furnace body. The main sources of water contamination are equipments of wet cleaning of BF gas such as gas scrubbers, venturi scrubbers and electrostatic precipitators with wet cleaning. They mostly use recirculating water circuits that become heavy contaminated with suspended solids and different dissolved matters, e.g. alkaline salts, zinc, lead, fluoride and cyanide components etc. A part of the contaminated water is released from clarifies - thickeners as a sludge and a new volume of clean technical water is added instead.

BF-sludges from top gas cleaning systems are first settled and dewatered in lagoon (if available), next dewatered and thickened by various types of filters and at the end dumped. Dissolved matters e.i. zinc, lead, and fluoride compounds have to be removed from water by precipitation techniques; cyanides and phenoles are destroyed by oxidation. Sludges and precipitation products with high content of harmful matters should by dumped on specialised dumping site because of groundwater contamination hazard.

BAT for Blast furnaces plant

1. Complex BF gas recovery (heat as well as pressure energy).
2. Direct injection of reduction agents into the blast furnace hearth.
3. BF gas pressure energy recovery.
4. Recovery of sensible heat of Cowpers off -gases.
5. Use of tar-free runner masses, which are not harmful to human health.
6. High efficiency BF gas cleaning system usage.
7. Blast furnace cast houses (tap hole, skimmers, runners, charging points) de-dusting.
8. Minimisation of emission from blast furnace slag treatment.
9. Waste water treatment from BF gas wet cleaning system.
10. Secondary products generation (solid wastes, by-product) and their complex utilisation and minimisation.

Basic Oxygen Steelmaking

The main objective of BOF steel making is to remove by oxidation undesirable elements still contained in a hot metal.

By blowing of oxygen into the converter an off-gas is created that is very rich in CO. In addition, it contains about 15 - 80 kg of solid dust particles per ton of produced steel.

Air pollution by BOF steelmaking process

There are two potential routes how to utilize converter gas. Older installations combust the BOF gases with air at the mouth of the converter vessel. Heat, both sensitive and chemical, is recovered in the form of steam generation in the boilers of ducting system.

In the second route, which is used in more modern installations, BOF gas is collected in gasholder and effectively recovered as very valuable gas fuel within steelworks.

In both cases BOF gas treatment plant used for solid dust particles removing, is essential. Post-combustion cleaning in the first case and cleaning prior to converter gas collection is used. Dry cyclones, wet venturi scrubbers and dry or wet electrostatic precipitators for BOF gas treatments are used. When unburned converter gas must be released to atmosphere, it should be flared because of the toxic carbon monoxide (CO) content.

Water pollution

Recycling water system is used for wet cleaning of BOF primary gas cleaning. In recirculation water, circuit removes of solid particles and cooling of water is employed. Removal of the solid particles is usually performed in two stages. In the first one coarse particles are removed by settlement. In the second one fine solid particles are removed in settlement tanks or clarifiers by sedimentation. Usually the sedimentation is supported by flocculation additives. The sedimentation process produces sludge that has to be next treated in thickeners followed by some kind of filter. Dewatered waste material is in most cases reused by briquetting or dumped or landfilled.

The recirculating water or water from settlement tanks and filter can contain soluble salts of some heavy metals like zinc or lead and should be treated prior to discharge to water recipients.

Soil and land pollution

The sludge that arises from the BOF gas treatment plant is rich in Fe content; often it contains more than 60 - 70 % of Fe_2O_3. In relation to steel scrap quality used in BOF steel production, the sludge may contain high amounts of heavy metals like zinc, lead and tin. If contents of these elements are acceptable the sludge can be recycled to sinter plant or, after briquetting or pelletising, directly to BOF charge. Increased contents of volatile heavy metals restraint utilisation of the BOF sludges that must be dumped or landfilled. Very strict countermeasures should be adapted to avoid contamination of ground or surface waters by dumped sludge eluates.

BOF dust hot briquetting and recycling

As it was mentioned, when contents of zinc and lead in BOF dust are very high and make its recycling via sinter production and blast furnace plants impossible, another option that avoids BOF dust dumping is its recycling into oxygen converter charge. The dust is recycled in form of briquettes made by hot-briquetting process. It produces the briquettes that not disintegrate in span of five days. The briquettes are charged to the empty converter vessel prior to steel scrap and hot metal charging.

By this way, valuable waste with high iron content can be saved. The overall iron yield is increased at about 1 %.

The main side effect of the process is that zinc and lead will concentrate in the dust, the recycling will increase their concentration in BOF dust. This fact will necessitate close monitoring of the dust composition. When the concentration of zinc and lead reaches a certain level (appropriate level is over 15% of Zn), the dust is rejected from recycling by BOF as well as sintering processes to be sold for non-ferrous metals industry.

BAT for basic oxygen steelmaking and casting

1. Effective dedusting of hot metal pre-treatment.
2. The most effective BOF primary gas dedusting.
3. The most effective secondary sources of dust (hot-metal treatment, reladling and charging of hot metal, steel tapping, deslaging, etc.) dedusting.
4. Minimisation of waste generation.
5. Minimisation of emission to water from BOF gas wet cleaning.
6. Minimisation of water contamination from direct cooling in continuous casting.
7. Minimisation of by-product generation (slags from skimming, slags from desulphurisation, dusts and sludges) and maximalisation of their utilisation.

Electric Arc Steelmaking

As electric arc furnace (EAF) melts steel scrap charge, there is less refining work when compared with BOF- steel making. On the other side, temperatures by EAF processing about 3000 °C, are able to volatilise metallic elements that are not released by BOF process.

Air pollution

Melting and refining processes in EAF generate large quantities of fume and dustes with high content of solid particles, metal oxides predominantly of iron, zinc and lead oxides and with CO, CO_2 and traces of HF, HCl and some hydrocarbons. Essential equipment for primary fume control is direct extraction of primary fume through a “second hole” or “fourth hole” in the furnace roof. Smaller furnaces with low capacity can use side-draught hoods, partial enclosures or canopies. They are located in areas of possible escape of fumes, i. e. de- slagging door, tapping spout and electrode ports.

In new installations the enclosure called doghouse is employed, that effectively closes whole EAF area. Fabric filters in cleaning plant capture the solid particles in the primary fume. Electrostatic precipitators are used only exceptionally concerning very high capacity furnaces.

Secondary fumes that escape during scrap preheating, charging and tapping are exhausted and dedusted mostly by roof capture systems in the furnace shop.

According to BREF, 98% and more collection efficiency of primary and secondary emissions from EAF steelmaking are achievable.

Water pollution

Close circuit-cooling systems for cooling of the furnace shell and roof are used that minimise releases of contaminated water-to-water sources.

Soil and land pollution

The EAF dusts captured by the fabric filters or by other devices are in most cases dumped. The dust is classified all over the world as dangerous waste that should be dumped on specialised dumping sites only. All necessary countermeasures should be employed to avoid contamination of ground and surface water with soluble salts of heavy metals. From this point of view, the use of landfilling is inacceptable.

Many methods exist for EAF dust and for zinc and lead recovery. Attempts for recycling of EAF dust after briquetting into EAF charge are promising, but only some of producers could this process industrially employ up to present. As EAF dust usually contains high quantities of zinc and lead oxides, its recovery mostly by Waeltz Kiln process is economically effective and employed in many applications.

Bat EAF steelmaking

1. Effective dedusting of furnace inside space, doghouse and electric arc furnace shop.
2. Minimisation of PCDD/F and PCB emissions.
3. Scrap preheating by sensible heat utilisation from EAF primary gas cleaning.
4. Minimisation of by-products generation.
5. Closed loop water-cooling system for furnace devices cooling.

CONCLUSION

In conclusion, a few more points relating to the IPPC Directive are presented.

During the years 1997 - 2001 the EUROFER as a representative body of the European steel industry participated in above mentioned information exchange. Results of this co-operation can be found in the next three important documents:

- the BREF for "Primary and Secondary Iron and Steel Making", issued in March 2000;
- the BREF for "Ferrous Metal Processing", which covers hot and cold rolling and hot-deep galvanising, issued in August 2000;
- the BREF for "Metal Surface Treatment", issued in summer of 2001.

Secondly, the interaction space of IPPC Directive can be seen in "Study on Energy Management and Optimisation in Industry". The AEA Technology (UK) issued the study in July 2000 at the request of Environmental Directorate - General of the European Commission. Specialists of the AEA Technology have looked at the opportunities for IPPC by identifying potential energy savings option in processes covered by the IPPC directive. In conclusions of the study, IPPC Directive covers 100% of steel industry. Potential savings of energy for EU-15 steel industry producer was evaluated for 387 PJ.

Finaly, last very important document which topic is directly connected to IPPC Directive, is the "Industrial Pollution and Risk Management, The Handbook on Implementation of EC Environmental Legislation", issued by EC, 2000. The content of this handbook covers six most important Directives and Regulations, which are very closely concerned to industrial pollution and risk management.

REFERENCES

1. Council Directive 96/61/EC - IPPC - on Integrated Pollution Prevention and Control
2. Ch. Lister: European Union Environmental Law, A Guide for Industry, Wiley 1996
3. Processes Subject to Integrated Pollution Control. IPC Guidance Note. S2 2.01: Iron and Steel Making Processes. Environment Agency, U.K.
4. Dutch Notes on BAT for the Production of Primary Iron and Steel