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IMPLEMENTATION OF IPPC DIRECTIVE IN FOUNDRIES

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The paper deals with Integrated Prevention and Pollution Control (IPPC) Directive and its application in foundry industry. The minimization of emissions, efficient raw material and energy usage, optimum process chemical utilization, recovering and recycling of waste and the substitution of harmful substances are all important principles of the IPPC Directive. The following major activities are discussed from the point of view of specific pollution of environment: melting and metal treatment, preparation of moulds and cores, casting of molten metal into the mould, cooling for solidification and removing the casting from the mould, finishing of the raw casting. For foundries the focal points are air emissions, the efficient use of raw materials and energy, and waste reduction, in conjunction with any recycling and re-use options.

Key words: *environmental control, foundry industry, air emission, waste reduction, wastewater*

Primjena IPPC naputka u ljevačkoj industriji. Rad se bavi integriranim predradnjama i naputkom o kontroli zagađivanja (IPPC) i njenom primjenom u ljevačkoj industriji. Minimalizacija emisija, učinkovita uporaba sirovina i energije, optimalno korištenje kemijskih procesa, oporavljanje i recikliranje otpada, zamjena štetnih tvari, sve su to važna načela IPPC naputka. S točke gledišta specifičnog zagađivanja okoliša raspravlja se o slijedećim glavnim aktivnostima: taljenju, tretiraju metala, pripremanju kalupa i jezgri, lijevanju rastaljenog metala u kalup, hlađenje radi skrućivanja i vađenja odljevka iz kalupa, konačna obrada sirovog odljevka.

Ključne riječi: *kontrola okoliša, ljevačka industrija, emisije zraka, smanjivanje otpada, otpadna voda*

INTRODUCTION

The European foundry industry is the third largest in the world for ferrous castings and second largest for non-ferrous. The annual production of castings in the enlarged European Union amounts to 11,8 million tones of ferrous and 3,0 million tones of non-ferrous castings (in 2002 year). Germany, France and Italy are the top three production countries in Europe, with a total annual production of over 2 million tones of castings each. Total number of foundries (units) is around 3000 and total employment number is around 260.000 people. The foundry industry is predominantly still SME industry, with 80 % of companies employing less than 250 people.

The main markets served by the foundry industry are the automotive (50 % of market share), general engineering (30 %) and construction (10 %) sectors. A growing shift of the automotive industry towards lighter vehicles has been reflected in a growth in the market for aluminium and magnesium castings. While iron castings mostly (i.e. > 60 %) go to the automotive sector, steel castings find their market in the construction, machinery and valve making industries.

The foundry industry is a major player in the recycling of metals. Steel, cast iron and aluminium scrap is re-melted into new products. Most possible negative environmental effects of foundries are related to the presence of the thermal processes and the use of mineral additives. Environmental effects therefore are mainly related to the exhaust and off-gases and to the re-use or disposal of mineral residues. Emissions to air are the key environmental concern. The foundry process generates mineral dusts, acidifying compounds. products of incomplete combustion and volatile organic carbons. Dust is a major issue, since it is generated in all process steps, in varying types and compositions. Dust is emitted from metal melting, sand moulding, casting and finishing. Any dust generated may contain metal and metal oxide. In foundry process, emissions to air typically not are limited to one (or several) fixed point(s). The process involves various emission sources (e.g. from hot castings, sand, hot metal). A key issue in emission reduction is not only to treat the exhaust and off-gas flow, but also to capture it.

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Since foundries deal with a thermal process, energy efficiency and management of the generated heat are important environmental aspects. However, due to the high amount of transport and handling of the heat carrier (i.e. the metal) and its slow cooling, the recovery of heat is not always straightforward.

Foundries may have a high water consumption e.g. for cooling and quenching operations. In most foundries, water management involves an internal circulation of water, with a major part of the water evaporating. The water is generally used in cooling systems of electric furnaces (induction or arc) or cupola furnaces. In general, the final volume of waste water is very small. Nevertheless, when wet dedusting techniques are used, the generated waste water requires special attention. In high pressure die-casting, a waste water stream is formed, which needs treatment to remove organic (phenol, oil) compounds before its disposal.

IPPC DIRECTIVE AND BAT PRINCIPLE

The purpose of the Directive IPPC is to achieve integrated prevention and control of pollution arising from the activities listed in Annex I, leading to a high level of protection of the environment as a whole. The legal basis of the Directive relates to environmental protection. More specifically, it provides for a permitting system for certain categories of industrial installations requiring both operators and regulators to take an integrate, overall look at the pollution and consuming potential of the installation. The overall aim of such an integrated approach must be to improve the management and control of industrial processes so as to ensure a high level of protection for the environment as whole. The minimization of emissions, efficient raw material and energy usage, optimum process chemical utilization, to recovering and recycling of waste and the substitution of harmful substances are all important principles of the IPPC Directive. For foundries the focal points are air emissions, the efficient use of raw materials and energy, and waste reduction, in conjunction with any recycling and re-use options. The operator should take all appropriate preventive measures against pollution, in particular through the application of best available techniques (BAT) to improve their environmental performance.

IPPC Directive is covering pollution of air, water, soil by emissions (gases, particulate matters, heat, noise and vibration), generation of wastes, and waste treatment processes, consumption of energy and raw materials, accidents and local contamination.

IPPC Directive covers six principal categories of the industrial production:

- energy industry,
- production and processing of metals,
- mineral industry,
- chemical industry,
- waste management,
- other activities (production of pulp and paper, some food agricultural activities).

One of the most important issues of the IPPC Directive is application of the BAT principle. The BAT descriptions contain mainly:

- characteristics of the process technology,
- specific production of emissions, waste and by-product generation, needs for consumptions of raw materials and energy inputs,
- the most effective technologies related to decreasing of emissions and waste rates and to increasing of energy savings,
- identification of BAT technologies,
- the new and developed technologies and processes.

BEST AVAILABLE TECHNIQUES (BAT) FOR FOUNDRY PROCESSES

General BAT for foundry processes

Some BAT elements are general and apply for all foundries, regardless of the processes they apply and the type of products they produce. This concerns material flows, finishing of castings, noise, waste water, environmental management and decommissioning.

Material flows

The foundry process involves the use, consumption, combination and mixing of various material types. BAT requires the minimisation of raw material consumption and the furthering of residue recovery and recycling. Therefore, BAT is to optimise the management and control of internal flows.

BAT for material flow is to:

1. apply properly storage and handling methods for solids, liquids and gases,
2. apply the separate storage of various incoming materials and material grades preventing deterioration and hazards,
3. carry out storage in such a way that the scrap in the storage area is of an appropriate quality for feeding into the melting furnace and that soil pollution is prevented,
4. apply internal recycling of scrap metal,
5. apply the separate storage of various residue and waste types to allow re-use, recycling or disposal,
6. use bulk or recyclable containers,
7. use simulation models, management and operational procedures to improve metal yield and optimise material flows,
8. implement good practice measures for molten metal transfer and ladle handling.

Finishing of castings

For abrasive cutting, shot blasting and fettling, BAT is to collect and treat the finishing off -gas using wet or dry system. The BAT associated emission level for dust is 5 to 20 mg/Nm^3.

BAT for heat treatment is to:

1. use clean fuels (i.e. natural gas or low-level sulphur content fuel) in heat treatment furnaces,
2. use automated furnaces operation and burner/heater control,
3. capture and evacuate the exhaust gas from heat treatment furnaces.

Noise reduction

BAT for noise reduction is to:

1. develop and implement a noise reduction strategy, with general and source-specific measures,
2. use enclosure systems for high-noise unit operations such as shake-out,
3. use additional measures, according to local conditions.

Waste water

BAT for waste water is to:

1. keep waste water types separate according to their composition and pollutant load,
2. collect surface run-off water use oil interceptors on collection system before discharge to surface water,
3. maximize the internal recycling of process water and the multiple used of treated waste water,
4. apply waste water treatment for scrubbing water and the other waste water flow.

Reduction of fugitive emissions

BAT is to minimise fugitive emissions arising from various non-contained sources in the process chain, by using a combination of different measures.

The emissions mainly involve losses from transfer and storage operations and spills. Fugitive emission may arise from the incomplete evacuation of exhaust gas from contained sources, e.g. emission from furnaces during opening or tapping. BAT is to minimise these fugitive emissions by optimising capture (nearest to the source) and cleaning of fume.

BAT for reduction of fugitive emission is to:

1. avoid outdoor and uncovered stockpiles, but where outdoor stockpiles are unavoidable, to use sprays, binders, stockpiles management techniques, windbreaks, etc.,
2. cover skip and vessels,
3. vacuum clean the moulding and casting shop in sand moulding foundries,
4. clean wheels and roads,
5. keep outside doors shut,
6. carry out regular housekeeping,
7. hooding and ducting design to capture fume arising from hot metal, furnace charging, slag transfer and tapping,
8. applying furnace enclosures to prevent the release of fume losses into atmosphere,
9. applying roofing collection, although this is very energy consuming and should only be applied as a last resort.

Decommissioning

BAT is to apply all necessary measures to prevent pollution upon decommissioning. In these measures, at least the following processes part are considered: tanks, vessel, pipework, insulation, lagoons and landfills.

BAT for decommissioning is to:

1. minimizing later risks and costs by careful design at the design stage,
2. developing and implementing an improvement program for existing installations,
3. developing and maintaining a site closure plan for new and existing installations.

BAT for particular foundry processes

Ferrous metal melting

Steel is melted in both electric arc furnaces (EAF) and induction furnaces. The choice between furnace types is based on technical criteria (e.g. capacity, steel grade). Due to its refining ability, the EAF allows the melting of lower grade scrap.

This is advantage in terms of the recycling of metals, but requires an appropriate flue-gas capture and cleaning system (Table 1.).

Table 1. **Emission to air associated with the use BAT for ferrous metal melting and treatment**
Tablica 1. **Emisije u zrak vezane za uporabu najbolje primjenljivih tehnika za taljenje i tretman metala željeza**

Parameter	Emission level
Dust*	5 - 20 mg/Nm^3
PCDD/PCDF	$\leq$ 0,1 ng TEQ/Nm^3

* The emission level of dust depends on the dust components, such as heavy metals, dioxins and its mass flow

For cast iron: cupola, electric arc, induction and rotary furnaces are applicable. The selection will be based on technical and economical criteria.

BAT for ferrous metal melting process

For the operation of electric arc furnace BAT is:

1. applying of reliable and efficient process controls to shorten the melting and treatment time,
2. using of the foamy slag practice,
3. efficiently capturing of the furnace off-gas,
4. cooling of the furnace off-gas and dedusting using a bag filter (Table 2.),

Table 2. **Emission to air associated with the use of BAT for the EAF melting of ferrous metals**

Tablica 2. **Emisije u zrak vezane za uporabu najbolje primjenljivih tehnika za EAF (elektrolučno) taljenje metala željeza**

Parameter	Emission level / (mg/Nm^3)
NO_x	10 - 50
CO	200

5. recycling of the filter dust into EAF furnace.

For the operation of cupola furnaces BAT is:

1. using of divided blast operation (2 rows of tuyeres) for cold blast cupolas,
2. using of oxygen enrichment of the blast air with oxygen levels 22 to 25 % (i.e. 1 to 4 % enrichment,
3. minimizing of the blast-off periods for hot blast cupolas by applying continuous blowing or long campaign operation,
4. using of coke with known properties and of a controlled quality,
5. cleaning of furnace off-gas by collection, cooling and dedusting using a bag filter or wet scrubber (Table 3.).

Table 3. **Emission to air associated with the use BAT for the cupola melting of ferrous metals**

Tablica 3. **Emisije u zrak vezane za uporabu najbolje primjenljivih tehnika za topljenje metala željeza u kupoli**

Type	Parameter	Emission level / (mg/Nm^3)
Hot blast	CO	20 - 1000
	SO_2	20 - 100
	NO_x	10 - 200
Cold blast	SO_2	100 - 400
	NO_x	20 - 70
	NM - VOC	10 - 20
Cokeless	NO_x	160 - 400

6. applying of post combustion the off-gas and heat recovery,
7. evaluating of the possibility of waste heat utilization from holding furnaces in duplex configuration,
8. using of wet scrubber system when melting with basic slag (basicity up to 2),
9. preventing and minimizing of dioxins and furan emission to a level below 0,1 ng TEQ/Nm^3,
10. minimizing of slag forming,
11. pretreating of the slags in order to allow their external re-use,
12. colleting and recycling of coke breeze.

For the operation of induction furnaces BAT is to:

1. melt clean scrap, avoiding rusty and dirty inputs and adhering sand,
2. use good practice measures for the charging and operation,
3. use medium frequency power,
4. evaluate the possibility of waste heat recuperation and under specific conditions to implement a heat recovery system,
5. use a hood, lip extraction or cover extraction on each induction furnace to capture the furnace off-gas and maximize the off-gas collection during the full working cycle,
6. use dry flue-gas cleaning and keep dust emissions below 0,2 kg/tone of molten iron.

For the operation of rotary furnaces BAT is to:

1. implement measures to optimize furnace yield and to use an oxyburner,
2. collect the off-gas close to the furnace exit, apply post combustion, cool it using a heat-exchanger and then to apply dry dedusting (Table 4.),

Table 4. **Emissions to air associated with the use of BAT for the rotary melting of ferrous metals**

Tablica 4. **Emisije u zrak vezane za uporabu najbolje primjenljivih tehnika za rotaciono taljenje metala željeza**

Parameter	Emission level / (mg/Nm^3)
SO_2	70 - 130
NO_x	50 - 250
CO	20 - 30

3. prevent and minimize dioxins and furan emissions to a level below 0,1 ng TEQ/Nm^3.

For ferrous metal treatment processes BAT is:

1. in AOD converter, to extract and collect the exhaust gas using a roof canopy,
2. for production of nodular iron to select a nodularisation technique with no off-gas production or to capture the produced MgO smoke and dedust the exhaust gas using a bag filter and make the MgO-dust available for recycling.

Non-ferrous metal melting

For aluminium melting multiple furnace types are applied. The selection of the furnace type is based on technical criteria. For melting of copper, lead and zinc and their alloys, induction or crucible furnaces are used. For copper alloys, hearth type furnaces are used as well. For magnesium melting, only crucible furnaces are used. A cover gas is used to prevent oxidation.

BAT for induction furnaces melting aluminuium, copper, lead and zinc is to:
1. use good practice measures for charging and operation,
2. use medium frequency power,
3. evaluate the possibility of waste heat recuperation,
4. minimise emissions and if needed to collect the furnace off-gas, maximising the off-gas collection during the full working cycle and apply the dry dedusting.

For the other furnace types BAT mainly focuses on the efficient collection of furnace off-gas and/or the reduction of fugitive emissions. BAT for the degassing and cleaning of aluminium is to use a mobile or fixed impeller station with Ar/Cl_2 or N_2/Cl_2 gas.

For melting of magnesium in installations with an annual output of 500 tones and more BAT is to use SO_2 as a covering gas. For smaller plants BAT is to use SO_2 or to minimize SF_6 consumption and emissions. In the case where SF_6 is used consumption level is < 0,9 kg/ton of castings for sand casting and < 1,5 kg/ton of castings for pressure die-casting.

BAT for dust for non-ferrous metal melting treatment is 1 to 20 mg/Nm^3. The emission factor associated with BAT for dust emission from aluminium melting is 0,1 to 1,0 kg/tone of molten aluminium (Table 5.). In order to comply with these BAT associated emission levels it may be necessary to install a flue-gas cleaning installation; in this case BAT is to use dry dedusting.

Table 5. **Emissions to air associated with the use of BAT in the melting of aluminium**
Tablica 5. **Emisije u zrak vezane za uporabu najbolje primjenljivih tehnika pri taljenju aluminija**

Type	Parameter	Emission level / (mg/Nm^3)
General	Chlorine	3
Shaft	SO_2	30 - 50
	NO_x	120
	CO	150
	VOC	100 - 150
	SO_2	15
Hearth	NO_x	50
	CO	5
	TOC	5

Lost mould casting

Lost mould casting involves moulding, core-making, pouring, cooling and shake-out. This includes the production of green sand or chemically-bonded sand moulds and chemically-bonded sand cores.

BAT for lost mould casting process
BAT elements can be presented in three categories:

green sand moulding:
1. mixing of sands, clay binder and necessary additives may be done in atmospheric or vacuum mixers. For vacuum mixing, an additional condition is that the sand capacity needs to be higher than 60 t/h,
2. enclosing of all the unit operations of the sand plant and to dedusting of the exhaust gas. The captured dust is made available for external re-use.
3. appling of primary regeneration.

chemically-bonded sand mould and core-making is to:
1. minimize the binder and resin consumption and sand losses, using control measures,
2. capture exhaust gas from the area where cores are prepared, handled and held prior to dispatching,
3. use water-based coatings and replace alcohol-based coatings for refractory coating of moulds and cores, where it is possible; when alcohol-based coatings are used BAT is to provide evacuation at the coating stand, using movable or fixed hoods,
4. treat the evacuated exhaust gas for amine-hardened urethane-bonded (cold-box) core preparation the amine emission can be maintained below 5 mg/Nm^3,
5. minimize the amount of sand going to disposal by adopting a strategy of regeneration and/or re-use of chemically-bonded sand (as mixed or monosand).

In Table 6. are given emission levels associated to the BAT measures for lost mould casting process. All associated emission levels are quoted as an average over the practicable measuring period.

Table 6. **Emission to air associated with the use of BAT for moulding and casting using lost moulds**
Tablica 6. **Emisije u zrak vezane za uporabu najbolje primjenljivih tehnika za kalupljenje i lijevanje pomoću preciznih kalupa**

Emission source	Parameter	Emission level / (mg/Nm^3)
General	Dust	3 - 20
Core shop	Amine	5
Regeneration unit	SO_2	120
	NO_x	150

Permanent mould casting

Permanent mould casting involves the injection of molten metal into a metal mould. Chemically-bonded sand cores are used to a limited extent in gravity and low-pressure die-casting.

BAT for permanent mould casting process

BAT for permanent mould preparation is to:

1. minimize the consumption of the release agent and water,
2. collect run-off water into a waste water circuit for further treatment,
3. collect water leakage liquid from hydraulic system into a waste water circuit for further treatment, using oil interceptors and distillation, vacuum evaporation or biological degradation,
4. enclose the de-coring unit, and to treat the exhaust gas using wet or dry dedusting.

In Table 7. are given emission levels associated to the BAT measures for permanent mould casting process. All associated emission levels are quoted as an average over the practicable measuring period.

Table 7. **Emission to air associated with the use of BAT for permanent mould casting**

Tablica 7. **Emisije u zrak vezane za uporabu najbolje primjenljivih tehnika za permanentno lijevanje u kalupe**

Parameter	Emission level / (mg/Nm^3)
Dust	5 - 20
Oil mist, measured as total C	5 - 10

CONCLUSIONS

The foundry industry is a major player in the recycling of metals. Steel, cast iron and aluminium scrap can all be re-melted into new products. The possible negative environmental effects of foundries result from the presence of a thermal process and the use of mineral additives. The environmental effects of a foundry process therefore are mainly related to the exhaust and off-gasses and the re-use or disposal of mineral residues.

The foundry industry is a differentiated and diverse industry. The elements of BAT applicable to a specific foundry need to be selected according to the type of activity. The emission and consumption levels associated with the use BAT have to be seen together with any specified reference conditions. Data concerning costs have been taken into account together with the description of the techniques. The actual cost of applying a technique will depend strongly on the specific situation regarding, for example, taxes, fees, and the technical characteristics of the installation concerned.

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