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Replies to Challenges in the Field of Air Pollution Control in Foundry Plants

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Abstract

The solution of applications for air pollution control in foundries for iron and non-ferrous metals may not only be understood as the observance of requested emission limit values at the stack outlet. An effective environmental protection already starts with the greatest possible capture of pollutants at the source with at the same time minimisation of the volume flow necessary for this. Independent of this, the downstream installed filtration system has to realise a degree of separation of definitely above 99%.

Furthermore, when selecting the filter construction, attention has to be paid to a high availability. An even temporarily production without filter will more and more no longer be accepted by residents and authorities. Incidents at the filter lead to a shutdown of the whole production.

Additional measures for heat recovery while preparing concepts for filtration plants help to reduce the energy consumption and serve for a sustained conservation of environment.

A consequent consideration of the items above is also condition for the fact that environmental protection in foundries remains affordable. The lecture deals with the subjects above from the point of view of a plant constructor.

Keywords: Air Pollutant Control, Absorption, Adsorption, Extraction systems

1. Introduction

In iron and non-ferrous metals foundries a multitude of different work processes take place, beginning with the melting process up to the finish treatment of castings during which emissions are escaping to the ambient air. The sustained environmental protection requires a nearly complete capture of these pollutions and their highly efficient separation from the gas/air in a filtration plant. In this connection the legislation has issued country-related regulations. Furthermore, there is an aspiration in the EU for a standardisation of limit values. This is realised with the BREF notes [1].

The observance of requested emission limit values is often continuously monitored. Even temporarily arising emissions are no longer accepted by the population. Problems at installed filtration plants lead to a shutdown of the complete plant, thus causing expensive losses in production. Filtration plants correspond to the state of the art have to ensure not only an efficient separation but also a high availability.

The operation of filtration plants entails additional operating costs which in the end have to be added to the sales cost of the products. Therefore, when selecting a solution for a system, not only the investment costs but also the operating costs have to be taken into consideration. In this connection attention has to be focussed to low maintenance and a low energy consumption. Additional measures for heat recovery should be considered for the corresponding application in question.

The following lecture discusses the aspects above from the point of view of a plant constructor.

2. Gas and particle collection

The effectiveness of a collection system for pollutants is of decisive importance for the quality of the whole suction system.

In this connection the extraction devices should be located as close as possible to the source of emissions to ensure the greatest possible suction at minimised volume flow. Maximal admissible workplace concentrations defined in codes of standards often serve as requirement for the definition of the minimal necessary degree of extraction. Proof of effectiveness can be given by means of immission measurements at the working place [2].

Beyond this the listed criteria below are used for the selection of a technical solution for an extraction system.

- *Minimisation of extraction air flow*
  The correct selection of extraction device can minimise the extraction air volume. Due to this the extraction device has a decisive influence on the height of overall investment and the power consumption of a plant for air pollution control.
- *Consideration of flow-related regularities*
  The achievable degree of extraction has a same high relevance for the overall plant as the filter efficiency. Very good degrees of separation remain without effect on the air pollution control if the dangerous substances are not collected to a great extent (Figure 1).
- *Handling and arrangement*
  The extraction device shall hinder the work process as few as possible. A simple handling and a trouble-free working are conditions for the acceptance of the user. The physically most suited solution becomes worthless if it will not be applied by the operator because of its restrictions of work.

The practically possible solution often presents a compromise between the requirements above. Figure 2 exemplary shows the extraction hood for an induction furnace. The scraps used for this application are containing a high portion of zinc.

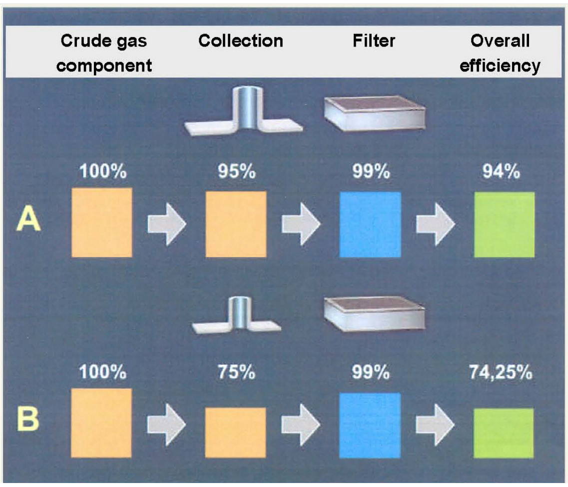

Fig. 1. Influence of collection system on the overall efficiency [2]

In connection with the numerous different operating modes to be considered, this makes special requirements on the extraction system.

Fig. 2. Suction hood for induction furnace

It may be remarked in addition that in case of complex applications, numeric flow simulations (CFD) are often realised beforehand to find an optimal solution.

3. Efficient particle separation

With regard to the separation of particles in foundries, fabric filters gained acceptance in comparison to other systems such as electrostatic precipitators or wet scrubbers. When using state-of-the-art fabric filters, degrees of separation far above 99% in continuous operation at high availability can be achieved. In the following the filter construction is explained by means of the flat-bag filter. Advantageous features for the realisation of high degrees of separation with at the same time low energy consumption are discussed.

3.1. Basic design of a fabric filter, exemplary shown by means of a flat-bag filter

Figure 3 shows the basic design of a fabric filter, using the example of a flat-bag filter with horizontally installed filter elements. The filter housing is divided into crude gas and clean gas area by means of perforated plates.

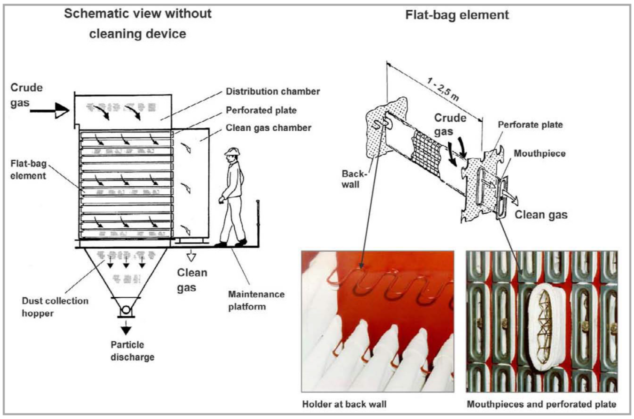

Fig. 3. Schematic view of flat-bag filter and filter element – horizontal installation

Horizontally arranged flat-bags, mounted on support cages, serve as filter elements. The installation in the filter housing takes place from the clean gas side. The flat-bag elements are precisely fitted in the housing. They are fixed in the holes of the perforated plate, secured without the use of screws and provide a perfect seal against dust leaks. The crude gas flow through the textile filter material is from outside to inside. Particles are retained on the outside.

3.2. Cleaning systems

Different processes are available for the cleaning of particles deposited in the filter and/or embedded in the filter fabric. Two systems frequently used for flat-bag filters in the foundry industry are described in the following.

3.2.1. Travelling compressed air -off line- cleaning (Figure 4)

The cleaning of the flat-bag rows takes place sequentially in steps by means of a cleaning device, travelling within the clean gas chamber and provided with compressed air feeding and injector tubes. The cleaning device covers three vertical filter bag rows, the middle of them being cleaned with a brief, about 0.5 sec., pulse of compressed air and clean gas as secondary gas. A lip seal along the carriage travel serves as reliable sealing, proved in continuous operation.

The cleaning of the flat-bag rows takes place sequentially in steps by means of a cleaning device, travelling within the clean gas chamber. The cleaning air is injected into one flat-bag row by means of a medium pressure fan, whilst the two adjacent flat-bag rows to the row being cleaned are not charged by the crude gas during the cleaning process. A lip seal along the cleaning air carriage travel serves as reliable sealing, proved in continuous operation.

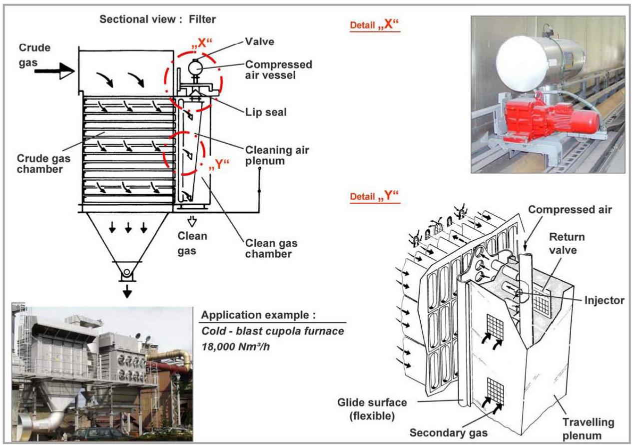

Fig. 4. Travelling compressed air – off line – cleaning

3.2.2. Travelling medium pressure -off line- cleaning (Figure 5)

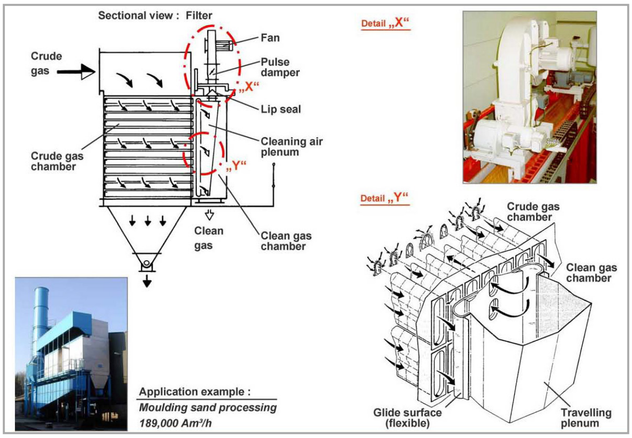

Fig. 5. Travelling medium pressure – off line – cleaning

This cleaning system does not require compressed air.

3.2.3. Advantageous features of -off line- working filter cleaning systems

Conventional compressed air - on line - cleaning devices have a serious disadvantage. As a result of the extremely short flow reversal in the filter fabric during the cleaning process, redeposits of a part of the cleaned particles are unavoidable and uncontrolled. The redepositing of particles takes place at a very unfavourable moment. In particular when the filter fabric fitfully hits on the support cage because of the backtracking force resulting from the pressure drop over filter. The result is a "carpet rapping effect" with an acceleration of particles towards the clean gas chamber. Beside an increased residual particle content, this hit back of filter fabric to the support cage leads to a comparatively high mechanical stress of the filter fabric.

Figure 6 demonstrates the influence of the cleaning procedure on the residual particle content in the clean gas. The graph shows the continuously measured residual particle content in the clean gas as well as the filter differential pressure over the time. The data have been measured at a filter with a comparatively small filter surface.

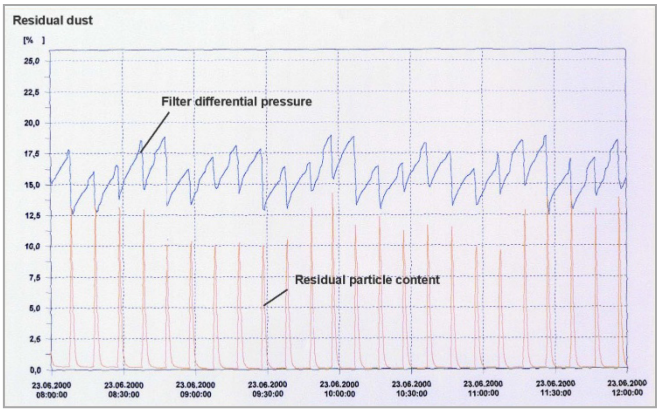

Fig. 6. Influence of the cleaning cycle on the residual particle content in the clean gas

It is clearly visible that after each -on line- cleaning procedure, there is an increase in particle passage which fairly quick falls down to a low level again. Offline working cleaning devices avoid the described disadvantageous aspects. During the cleaning procedure the filter fabric is smoothly led back to the support cage. A "carpet tapping effect" only occurs to a minor degree. In addition to this the particles have more time available for falling down into the collection hopper after the cleaning process.

3.3. Influence of gas inlet to the filter elements

(Figure 7)

The preferably unhindered falling down of separated particles in the filter housing is important for the realisation of long cleaning cycles and by this low mechanical stress of filter fabric. Beside the advantages of an -off line- cleaning system discussed in item 3.2, the gas inlet to the filter elements gains special importance in case of single-compartment filters. As far as single-compartment chamber filters will be used, an inlet from above has to be preferred.

In case of an inlet from below or diagonally from below, as applied for filters with vertically installed bags, a particle agglomerate removed from the filter fabric during cleaning can only fall down if its descent velocity is higher than the counter-flow velocity of gas inlet. Due to the fact that the descent velocity of particle agglomerates with about 200 µm only totals to approx. 1 m/sec., it is evident that in case of single-compartment filters exclusively a crude gas flow from above will be able to minimise undesired and uncontrolled particle redeposits, particularly of finest particles.

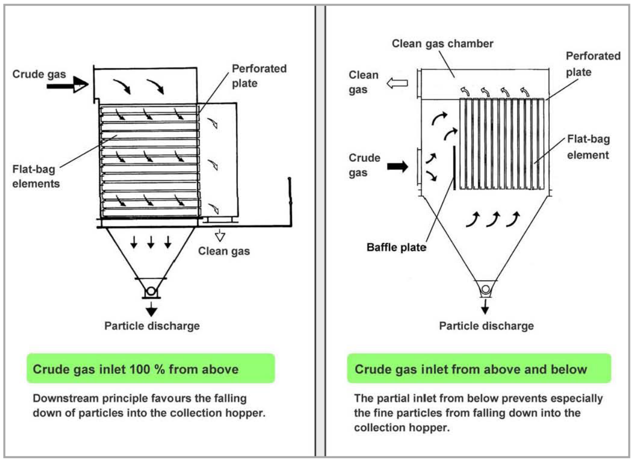

Fig. 7. Gas flow to the filter elements

4. Energetic consideration

4.1. Electrical energy

The aforementioned particular features of the flat-bag filter with regard to cleaning systems and filter inlet will, beside a highly-efficient particle separation, also lead to a reduction in electric power consumption as a result of a low filter differential pressure together with a long cleaning cycle.
Here it may additionally be pointed again to the optimal design of the extraction device particularly with regard to a minimal extraction volume flow. This offers a large potential for energy saving.

4.2. Heat recovery

Beside the heat recovery by means of heat removal from hot furnace off-gas, e.g. at hot blast cupola furnaces, there are further possibilities of heat recovery in foundries, for example in form of an air re-circulation into work rooms. This subject gains increasing importance not least in the scope of the CO_2 reduction degree. The following numerical example demonstrates the potential of possible energy saving. In case of a temperature difference between outdoor temperature and requested work room temperature of e.g. 20 K and an extraction volume flow of 100,000 Nm^3/h, the calculated energy saving totals to > 700 kWh/h.

During the air re-circulation, the air cleaned in a filter is redirected into the work room. In this connection very high demands are made on the quality of the re-circulated air. Normally the fabric filters are provided with a polishing filter stage. These simple, non-regenerative second filter stages realised as pocket-type or cassette filters allow clean gas dust contents of definitely < 0.1 mg/Nm^3. The air can safely be redirected into the work room. Further details can be taken from the literature [3].

5. Separation of acid crude gas components (HF, HCl, SO_x and dioxins and furans)

5.1. Preliminary remark

Fabric filters are generally only suitable for the separation of particles from gas. To allow the separation of gaseous components, these substances have to be converted into the particulate form by means of chemical reaction caused by the injection of additive powders (absorption) or have to be attached to the inner surface of adequate additive powders (adsorption).

Examples are:

- Absorption of acid crude gas components such as HF, HCl and SO_x by injection of additive powders based on Ca- or Na-compounds
- Adsorption of dioxins / furans by injection of additive powders with large inner surface such as e. g. activated coke, activated carbon or special clay minerals

5.2. Absorption of HF, HCl and SO_x

In general commercially available hydrated lime $Ca(OH)_2$ with a specific surface of approx. 18 – 20 m²/g is used as additive powder for the injection into the gas flow upstream filter. The reaction equation as well as the injection and remainder quantities at an additive powder efficiency of 100% are listed in Figure 8. To grant the reliable observance of the requested emission levels in the practise, the additive powder has to be injected above-stoichiometric (usually 1.5 – 3 fold).

Reaction equation	$Ca(OH)_2$ injection quantity related to crude gas at 100% stoichiometry (i=1)	Resulting residual particle quantity (with crystal water content accord. to experience) related to crude gas
$2HF + Ca(OH)_2 \rightarrow CaF_2 + 2H_2O$	1.85 kg/kg	1.95 kg/kg
$2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$	1.01 kg/kg	2.02 kg/kg
$SO_3 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$	0.93 kg/kg	2.15 kg/kg
$SO_2 + Ca(OH)_2 \rightarrow CaSO_3 + 2H_2O$	1.16 kg/kg	2.02 kg/kg

Fig. 8. Reaction equation for $Ca(OH)_2$

The realisation of a particle- and additive powder re-circulation demonstrably leads to a considerable improvement of the separation efficiency regarding acid crude gas components and/or to a reduction in the additive powder injection quantity.

- The residence time of additive powder particles within the system is increased
- There is a higher additive powder density near the reactor upstream filter (reaction time within reactor up to > 2 sec)
- A frequent spatial new orientation of the re-circulated additive powder particles with attachment to the filter fabric will be achieved

To ensure the reliable realisation of the re-circulation of particles separated in the filter into the gas flow upstream filter, the Conditioning Rotor - Recycle Process proved to be suitable for many applications (Figure 9). The conditioning rotor is a hollow cylinder made of a perforated plate with openings of approx. 30 x 30 mm. Up to 10% of its volume is filled with balls made of heat- and wear-resistant ceramics. The rotor is continuously rotating with approx. 1 rpm by means of a geared motor. The rotation causes the balls to move relatively to each other inside of cylinder and to the perforated shell. The rotor is passed through by the flue gas around its axis of rotation at first in downwards and finally in upwards direction.

The main functions of the conditioning rotor are:

- Avoidance of particle deposits when reversing a particle-laden gas flow
- Achievement of a homogeneous distribution of particles in the crude gas flow even in case of high particle loads (e.g. up to 50 g/m³)
- Disintegration of larger particle agglomerates

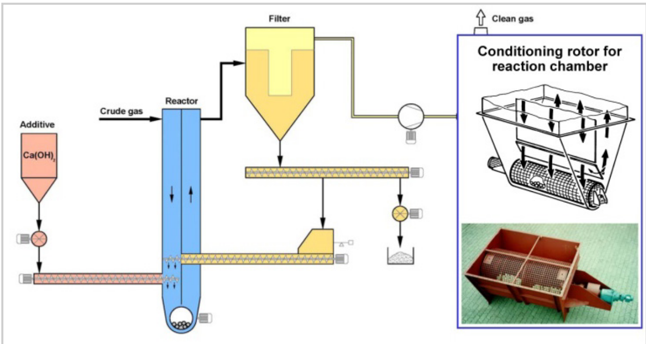

Fig. 9. Conditioning Rotor – Recycle Process (KUV)

Prior to being discharged out of the filter, the particles separated in the filter are repeatedly re-introduced into the reactor by means of a conveying screw. The particle recycle rate can be adjusted and can, if needed, be controlled e.g. subject to the current crude gas volume.

With regard to some realised projects, particularly in France and Italy, the reagent quality $NaHCO_3$ is used instead of $Ca(OH)_2$ for the separation of acid crude gas components. The disadvantage of this additive powder quality is i.a. the definitely higher purchase price but from case to case advantages may result regarding the recycling and/or disposal of remainders discharged from the filter. This lecture however, will not go into an exhaustive description of the corresponding process technology.

5.3. Adsorption of dioxins / furans

For the separation of gaseous dioxins/furans an additive powder quality with large specific surface is injected into the flue gas flow upstream fabric filter. The dioxins/furans are adsorbed at the additive powder particles and by this separated at the filter fabric. A multiple re-circulation of the particles separated in the filter has an advantageous influence on the achievable degrees of separation and/or leads to a reduction in operating costs regarding the additive powder consumption and disposal.

In most of the cases activated coke and/or activated carbon with a specific surface of approx. 350 up to > 1,000 m²/g are used as additive powder. Due to the fact that these qualities are carbonaceous additive powders, preventive measures have to be taken to avoid dust explosions and smoulder within the filter. Alternatively special clay minerals can be used instead.

Simultaneously realised crude and clean gas measurements at different gas cleaning systems downstream Al melting furnaces confirmed the efficiency of the Conditioning Rotor – Recycle Process as well for the separation of dioxins / furans at acceptable activated coke consumption (Figure 10).

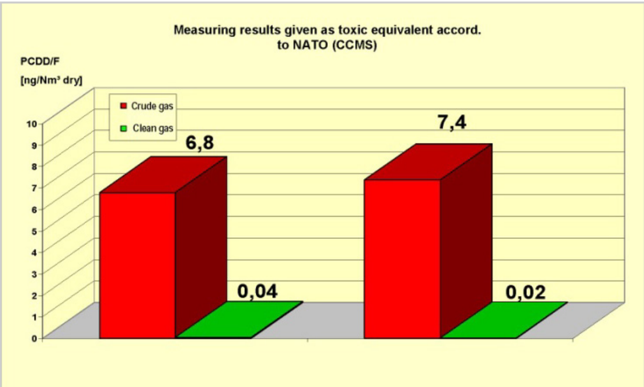

Fig. 10. Dioxin/ Furan separation from the off-gas of melting furnaces for secondary aluminium

6. Assessment

Air pollution control systems consisting of collecting device and fabric filter are in principle suited to meet, reliably and in continuous operation, the present and coming requirements regarding the requested degrees of separation. When selecting the type of gas cleaning system for a given application, the different extraction systems and filter constructions have to be assessed by comparison. The criteria to be considered are amongst others:

- arising investment costs
- arising operating costs, such as energy and compressed air consumption, expenditure of maintenance, filter fabric service life etc.
- efficiency of extraction system and degree of separation of filter
- availability and reliability
- references

Particularly the operating costs and the achievable availability are influenced by the filter construction. The aim is to select a variant which will among other things

- minimise the mechanical stress of the filter fabric
- allow long cleaning cycles
- keep the concentration of finest particles near the filter fabric as low as possible
- achieve a comparatively low filter differential pressure

Measures for energy saving and/or heat recovery should be considered depending on the application in question.

References

[1] BAT Reference Document, European IPPC Bureau
[2] Capture of air pollutants, VDMA 2006
[3] Luftrückführung, VDMA 2009