LÜHR FILTER

Separation of particles; acid crude gas components (HF, HCl, SOx) as well as dioxins/ furans from the off-gas of aluminium melting furnaces – Operating experiences gathered from the realisation of filtration plants in Europe -

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ALUSIL
The 5th International Conference and Exhibition
ALUMINIUM-21/RECYCLING

St. Petersburg – Russia – October 12-14.2010

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1 Introduction

Nowadays, the extraction of aluminium from secondary raw materials constitutes an important part of the overall production in Europe, thus reducing the consumption of the primary raw materials and also of the energy necessary for the production. The most important environmental problems arising during this process are the pollutants contained in the flue gas escaping from the melting furnaces, such as dust, metals and also acid gases. Due to the existence of minor chlorine quantities in the secondary raw materials, there is in addition the possibility of formation of dioxins / furans, which have to be destroyed or removed as far as possible from the gas prior to rejection of cleaned gases into the atmosphere.

This lecture deals with the separation of the pollutants mentioned above by means of fabric filters. The explanations are based on operating experiences gathered from plants realised by LÜHR FILTER in Europe since the beginning of the seventies till this day downstream different furnaces for the melting of secondary aluminium (pic. 1).

Rotary kilns / Germany

Tiltable rotary kiln / Russia

Hearth-type furnace / Belgium

Rotary kiln and induction furnace / France

Shaft furnace/ Germany

Pic. 1: Application examples for LÜHR flat-bag filters downstream melting furnaces for secondary aluminium

2 Emission limit values

Acting for the requirements regarding the max. emission limit values in Europe, table 1 shows the essential limit values requested by the German “Technical Instructions on Air Quality Control" (“Technischen Anleitung zur Reinhaltung der Luft“) (TA-Luft), dated 2002.
With regard to the member states of the European Community, additional measures concerning the reduction of emissions have been discussed in the „Reference document on best available technique in the Non Ferrous metals industries“ (BREF-Notes) dated 2001. These notes describe the best available technique (BVT) for the application in question. All over Europe they serve as basis for the approval of all new plants and have also to be implemented for existing plants. The limit values regarding the field of NE-metals industry lie in a similar range as the values defined in the TA-Luft. At present this document is in process of being revised.

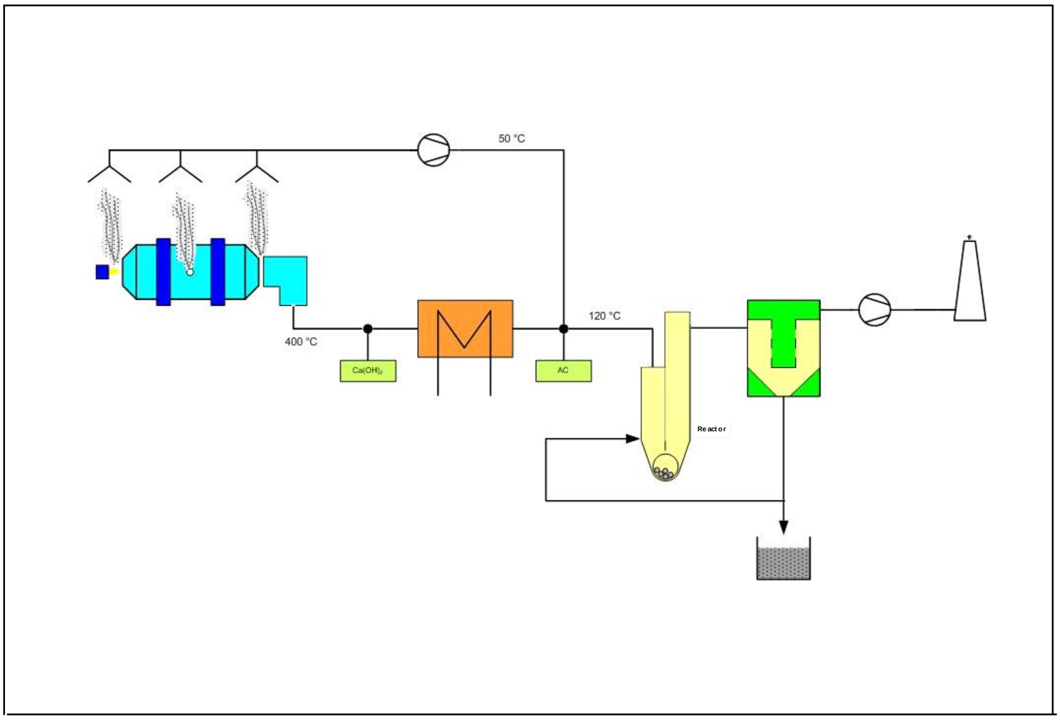
Substance	Limit value
Total dust	10 mg/Nm3 dry
Gaseous inorganic substances	
• HF	3 mg/Nm3 dry
• Cl2	3 mg/Nm3 dry
• HCl	30 mg/Nm3 dry
• SO2+SO3	350 mg/Nm3 dry
Dioxin/ Furan	0.1 ng/Nm3 dry

Tab. 1: Relevant limit values of TA Air 2002 for plants for the production of aluminium from secondary raw materials

3 Structure of process technology of gas cleaning system

Depending on the feedstock, normally hearth-type furnaces, tiltable rotary kilns, rotary kilns, induction furnaces or shaft furnaces are used as melting aggregates for secondary aluminium. The chosen type of kiln or even combinations of different types, influence the design of the gas collection systems for the emitting gas and the structure of the downstream installed gas cleaning system.

Picture 2 exemplary shows an often realised variant for the gas cleaning downstream rotary kilns. The heating and process gas is directed into a heat exchanger. Upstream heat exchanger, particulate additive powder, usually the quality $Ca(OH)_2$, is injected into the gas flow. This reagent serves on the one hand for the protection of downstream installed components against corrosion and on the other hand for the reduction of the acid crude gas components HCl and HF. In normal cases, an SO_x separation for the observance of emission limit values will not be necessary. After passing the heat exchanger, the gas is added via the hoods necessary for the capture of all emissions near the kiln. The gas cleaning takes place in a reactor – filter combination. To achieve the separation of dioxins / furans, an additive powder quality with large specific surface – normally the quality activated coke - is additionally injected near the reactor.

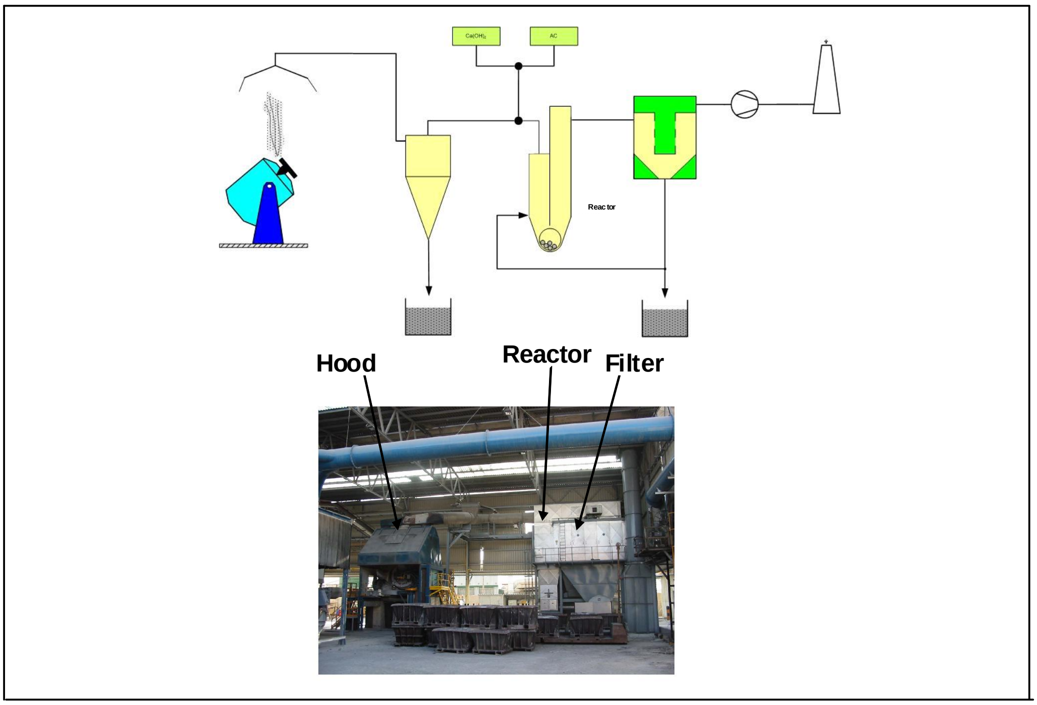


Pic. 2: Process scheme of a gas cleaning system for rotary kilns

In case of use of tiltable rotary kilns, the installation of a heat exchanger for the temperature reduction is often not necessary (pic. 3).

With regard to this type of kiln, the contaminated gas is collected by means of hood systems and is directed towards the gas cleaning system. In many cases, a cyclone is installed upstream of reactor – filter combination serving for the separation of particles with high heat energy (sparks).

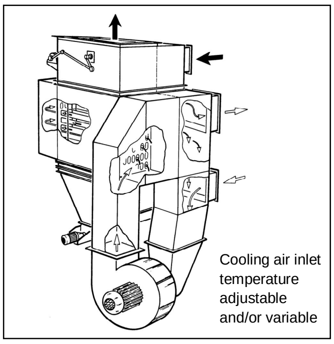
The process units necessary for the gas cleaning are described below.

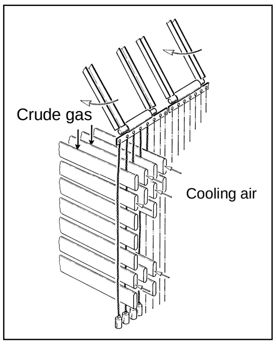


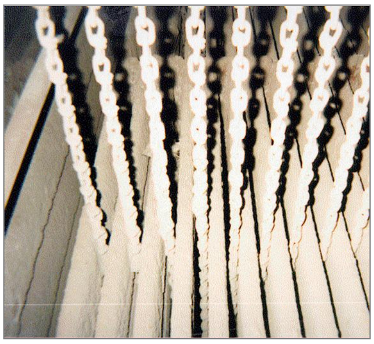
Pic. 3: Process scheme of a gas cleaning system for tiltable rotary kilns

4 Description of process units
4.1 Gas cooling

In case it will not be possible to grant the reliable observance of a max. air temperature of 160°C upstream filter, a recuperative heat exchanger will normally be installed upstream filter. Due to the quickly changing process temperatures, the use of other cooling variants, such as an evaporative cooler (water quench) cannot be recommended.







Heat exchanger / Fabric filter
Aluminium rotary kilns

Requirements on heat exchanger

- **Assurance of a sufficient cooling in continuous operation**
  - ⇒ **Mechanical cleaning of cooling surfaces by means of chains**
- **Avoidance of corrosions and deposits due to temperatures below the dew point**
  - ⇒ **Reduction of acid dew point by means of additive powder injection upstream heat exchanger**
  - ⇒ **Minimal cooling air inlet temperature larger or equal to water dew point**

Pic. 4: Recuperative heat exchanger using the example of LÜHR flat-tube heat exchanger

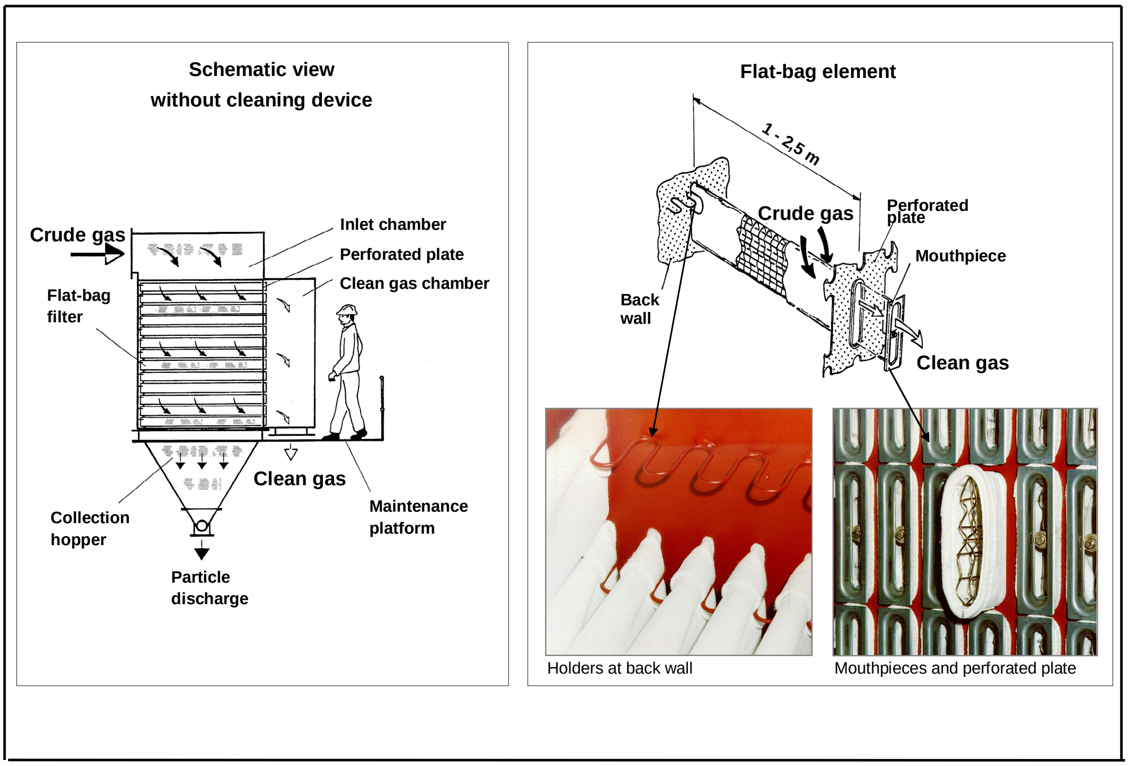
Picture 4 exemplary shows a schematic view of a flat-tube heat exchanger as gas / air heat exchanger. The cooling takes place by means of indirect heat exchange between the gas to be cooled and the ambient air taken in near the cooler. The flue gas to be cooled flows downwards and upwards and/or upwards and downwards between the horizontally located flat sided cooling tubes. A part of the heat is transferred through the external walls of the flat tubes to the cooling air flowing through the inside of the flat tubes.
The re-circulation of a portion of the cooling air and the additional additive powder injection into the flue gas flow prevent the temperature near the external walls of cooling tubes from falling below the water or acid dew point. Corrosion and particle deposits will be avoided.

Due to the strongly adhesive character of the particles existing downstream melting furnaces for secondary aluminium, an automatic cleaning device will be installed, working during the admission of heat exchanger. Chains are moving slowly to and fro the cooling tube rows, thus serving for the limitation of particle layer on the cooling tubes.
The integration of a heat recovery will e.g. be possible in form of a hot water generator.

4.2 Fabric filters

4.2.1 Basic design exemplary shown by means of a LÜHR flat-bag filter

The basic design of a fabric filter is shown in picture 5, representing a LÜHR flat-bag filter with horizontally installed filter elements. The filter housing is divided into a crude gas and a clean gas chamber by means of perforated plates.



Pic. 5: Fabric filter using the example of LÜHR flat-bag filter

The filter elements are horizontally installed flat-bags, mounted on support cages. The filter elements are inserted into the filter housing from the clean gas side. They are held in fixed positions in the filter housing, fitted precisely in the holes in the perforated plate, secured without the use of screws thus providing a perfect seal against dust leaks. The gas flow passes the textile filter fabric from the outside to the inside, the particles being retained on the outer surface of the filter elements.

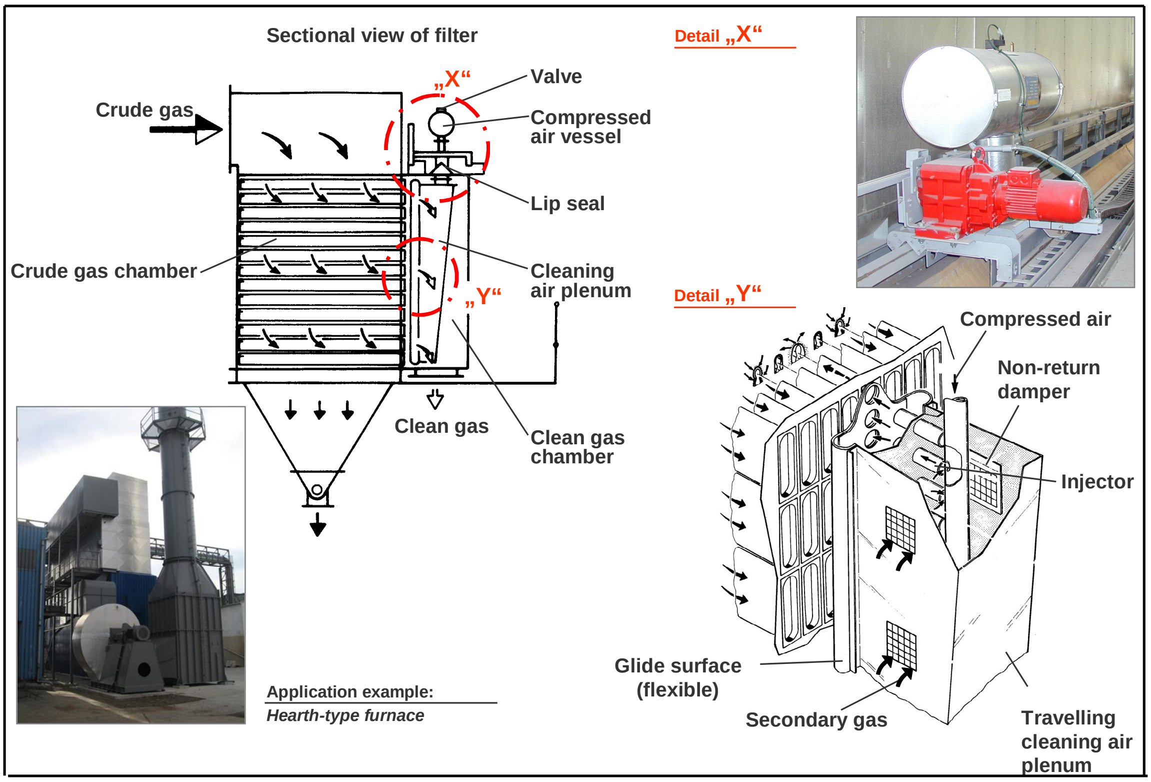
In addition it should be mentioned that alternatively a construction with vertically installed flat-bags is available. Even in this case, the flat-bag elements are precisely fitted in the housing, however, not all advantages of flat-bag filters with horizontally installed filter elements can be used consistently.

4.2.2 Cleaning systems

Different cleaning systems are available for the separation of particles deposited on or embedded inside of the filter fabric. Two types of cleaning systems, frequently used for flat-bag filters downstream aluminium melting furnaces, are described in the following.

4.2.2.1 Travelling compressed air -off line- cleaning

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 at a time, the middle of them being cleaned with a brief, about 0.5 sec. long, pulse of jet air and clean gas as secondary gas. A lip seal along the carriage travel serves as reliable sealing, proven in continuous operation.

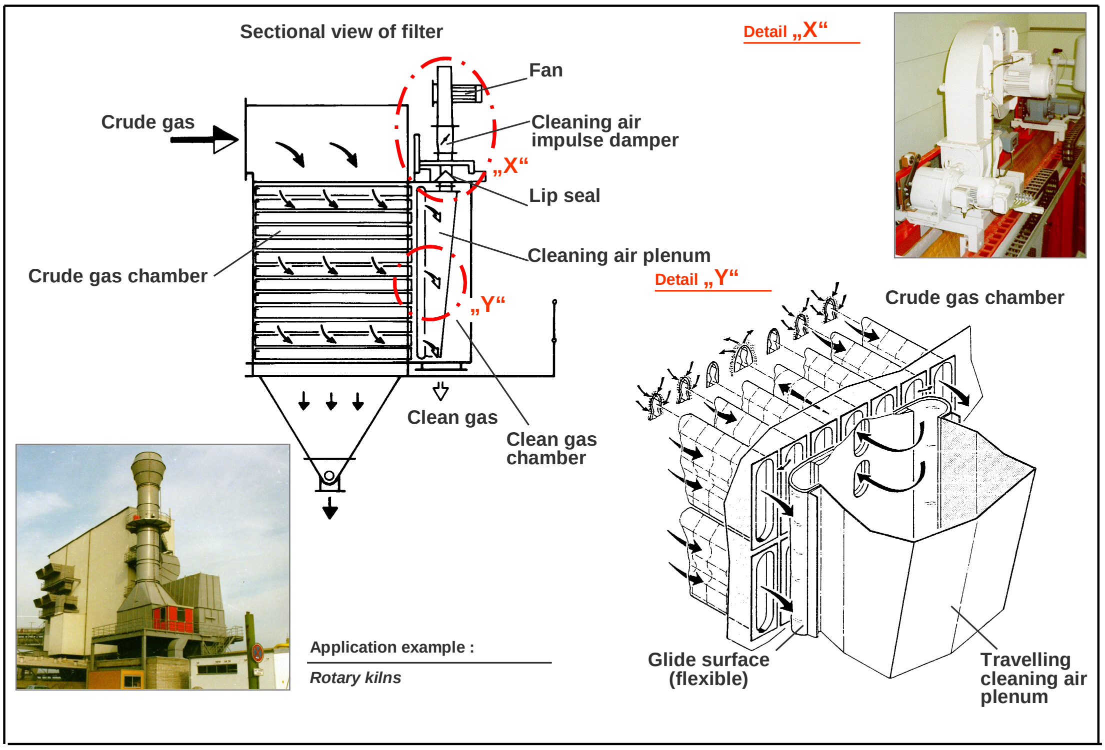


Pic. 6: Travelling compressed air - off line - cleaning system

4.2.2.2 Travelling medium pressure -off line- cleaning

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 at a time by means of a medium pressure fan. The two bag rows adjacent to the row being cleaned are not charged by the crude gas during the cleaning process. A lip seal along the carriage travel serves as reliable sealing, proven in continuous operation.

This cleaning system does not require any compressed air.



Pic. 7: Travelling medium pressure - off line - cleaning system

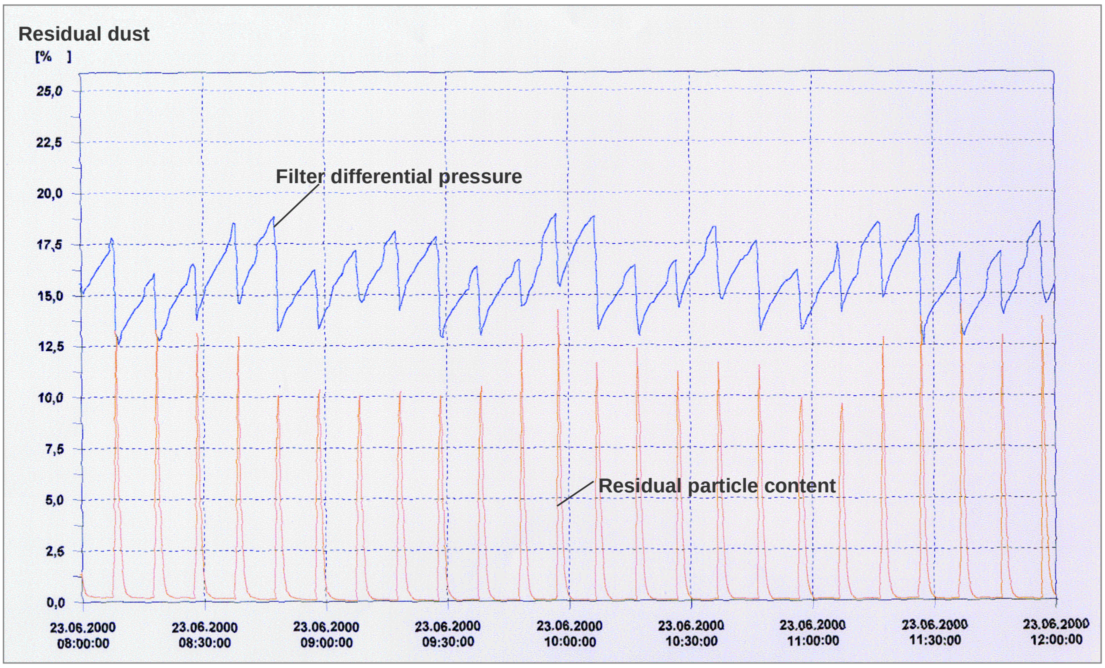
4.2.2.3 Advantageous features of the -off line- working filter cleaning

The application of conventional compressed air -on line- cleaning systems implies a serious disadvantage due to the extremely short flow reversal in the filter fabric during the cleaning. Re-deposits of separated particles are unavoidable and uncontrolled. The re-deposit takes place when the filter fabric impacts against the support cage after the cleaning pulse. The fine dust is literally catapulted through the fabric towards the clean gas side of the filter („Carpet wrapping effect“). The impact of filter fabric to the support cage causes not only an increase in the residual particle content on the clean gas side but also a comparatively high stress to the filter fabric.

Picture 8 illustrates the influence of the cleaning system on the residual particle content in the clean gas. It 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 collected at a filter with a comparatively small filter surface.

It is clearly visible that each -on line- cleaning procedure causes an increased particle passage which comparatively quickly drops to a lower level again.

The above-described disadvantages can be avoided by using -off line- cleaning devices. This type of cleaning system allows a gentle treatment of the filter fabric, there is no „Carpet wrapping effect“. In addition, the particles have more time to fall down into the collection hopper after the cleaning procedure. Particularly the travelling compressed air -off line- cleaning system is nowadays often used for flat-bag filters downstream aluminium melting furnaces because of the high efficiency in connection with low mechanical stress to the filter fabric.



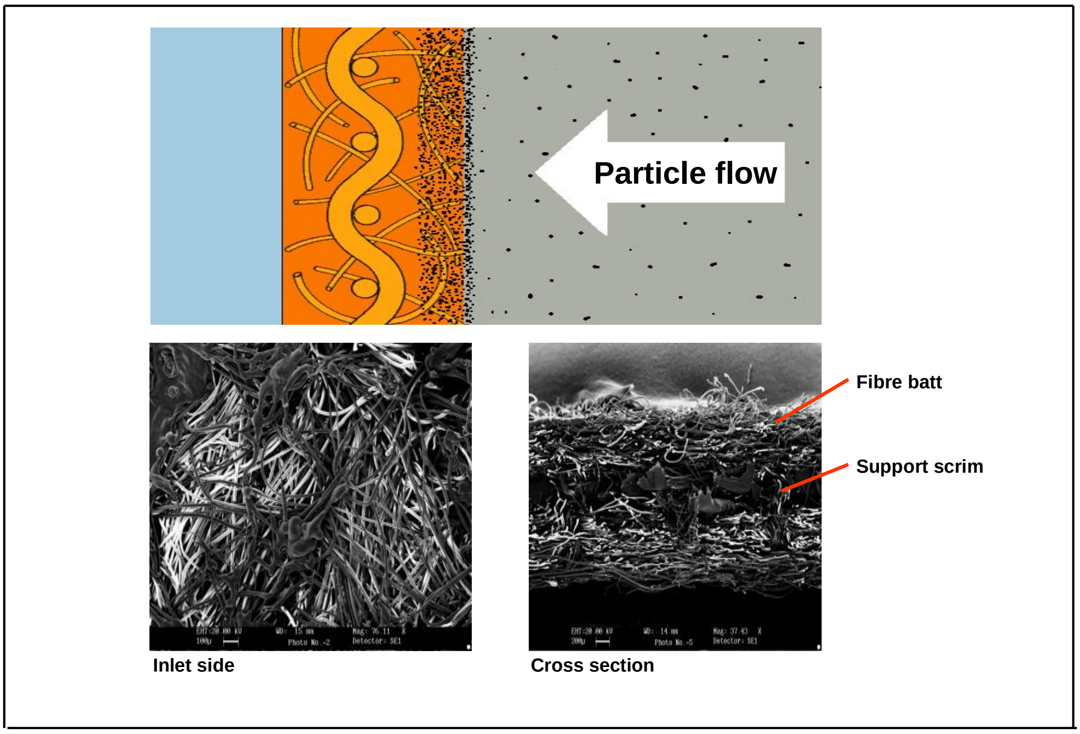
Pic. 8: Correlation filter cleaning – dust emissions

The main advantage in contrast to the travelling medium pressure -off line- cleaning system is the avoidance of temperatures below the dew point near the flat-bags during or shortly after the cleaning process.

4.2.3 Filter fabrics

The basic structure of the needle felts used as filter fabric is shown in picture 9. It consists of a support scrim with a fibre batt. A large number of different needle felt qualities is available. Table 2 shows the qualities preferably used for filters downstream aluminium melting furnaces and informs about the relation between needle felt purchase costs and the admissible operating temperatures.
The selection of a filter fabric quality and by this the setting of the flue gas temperature within the filter is subject to the requirements of the corresponding application. It is influenced among other things by:

- Gas composition
- Emission limit values to be observed
- Acid and water dew point
- Investment and operating costs



Pic. 9: Composition of a needle felt without surface treatment

The service lives of the filter bags installed in fabric filters downstream glass tanks total to at least two and well above five years. Condition for this is the selection of a filter type with gentle treatment of the filter fabric.

Continuous operating temperature based on practical experience	Needle felt: Fibre batt	Needle felt: Support scrim	Approx. multiple expenditure referred to Polyacryl needle felt
≤ 120°C Limited dependency on H_2O content	Polyester	Polyester	0.8
125°C	Polyacryl, e. g. Dolanit *)	Polyacryl, e. g. Dolanit *)	1.0
≤ 160°C Depending on H_2O content	Aromatic polyamide, e. g. Nomex *)	Aromatic polyamide, e. g. Nomex *)	2.6

Tab 2.: Selection of filter fabric

4.2.4 Constructive measures for ensuring low mechanical stress to the filter fabric

4.2.4.1 Support cage construction

Preferably support cages with a small wire mesh (in case of a flat-bag filter e.g. 25 x 25 mm) should be used, thus allowing a homogeneous distribution of the forces acting upon the filter bags as a result of the filter differential pressure on the complete filter fabric.

Pic. 10: Support cage of flat-bag filter element

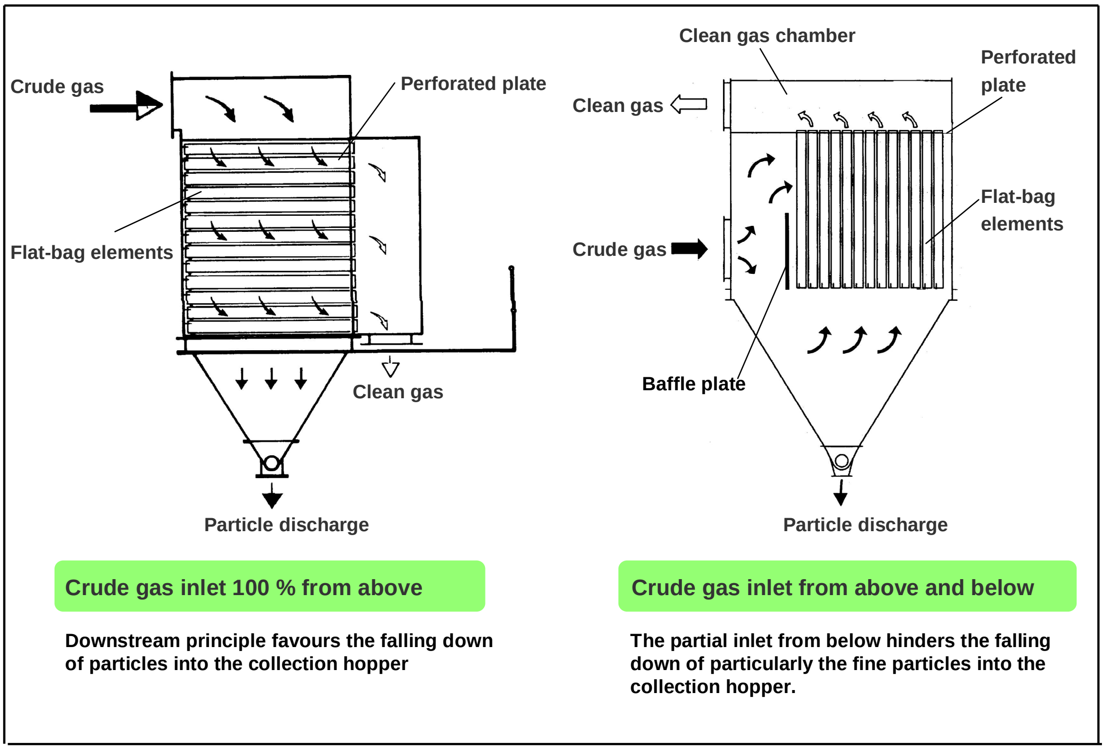
The size distribution of the arising forces can be explained with the help of a simple example: A filter differential pressure of 15 mbar (equivalent to 150 mm water gauge) corresponds to a load of 1,500 N/m². These surface forces have to be transferred from the filter fabric to the wires of the support cage. The narrower the wire mesh, the lower the stress to the textile filter material near the wires.

4.2.4.2 Filter inlet flow to the filter elements

An important precondition for the achievement of long cleaning cycles and by this low mechanical stress to the filter fabric is an undisturbed falling down of separated particles in the filter housing.

As far as one chamber filters are used, a flow inlet from above should be preferred.

In case of an inlet from below or diagonally from below at one chamber filters, the particles separated at the filter elements can only fall down, if the descend velocity is larger than the counteracting inlet gas flow. As the descend velocity of particle agglomerates of 200 μm totals to only approx. 1 m/sec, the top entry flow distribution in one chamber filters is the only way to minimise new, undesired and uncontrolled particle deposits particularly of finest particles.



Pic. 11: Different types of crude gas inlet to the filter elements

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 table 3. 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 – 3fold).

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**

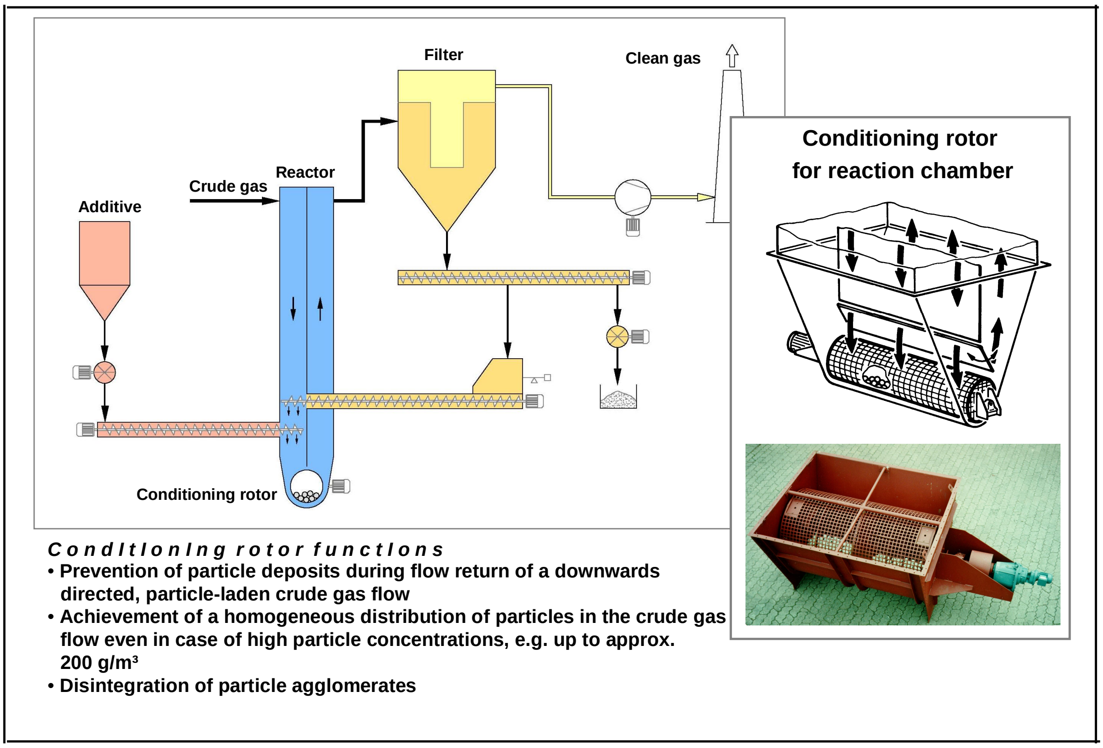
Tab. 3: Reaction equation for $Ca(OH)_2$

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 flue gas flow upstream filter, the Conditioning Rotor - Recycle Process proved to be suitable for many applications (pic. 12). 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 crude 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



Pic. 12: 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.

Compared to alternative, e.g. pneumatically working re-circulation systems, the Conditioning Rotor – Recycle Process offers the following advantageous features:

- Mechanical particle transport by means of reliable screw conveyors
- Discharge and possibly intermediate storage of recycled particulate prior to re-circulation is not necessary
- Securing of a homogeneous distribution of recycled particulate during injection in the crude gas flow by using the conditioning rotor
- High availability and operational reliability

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.

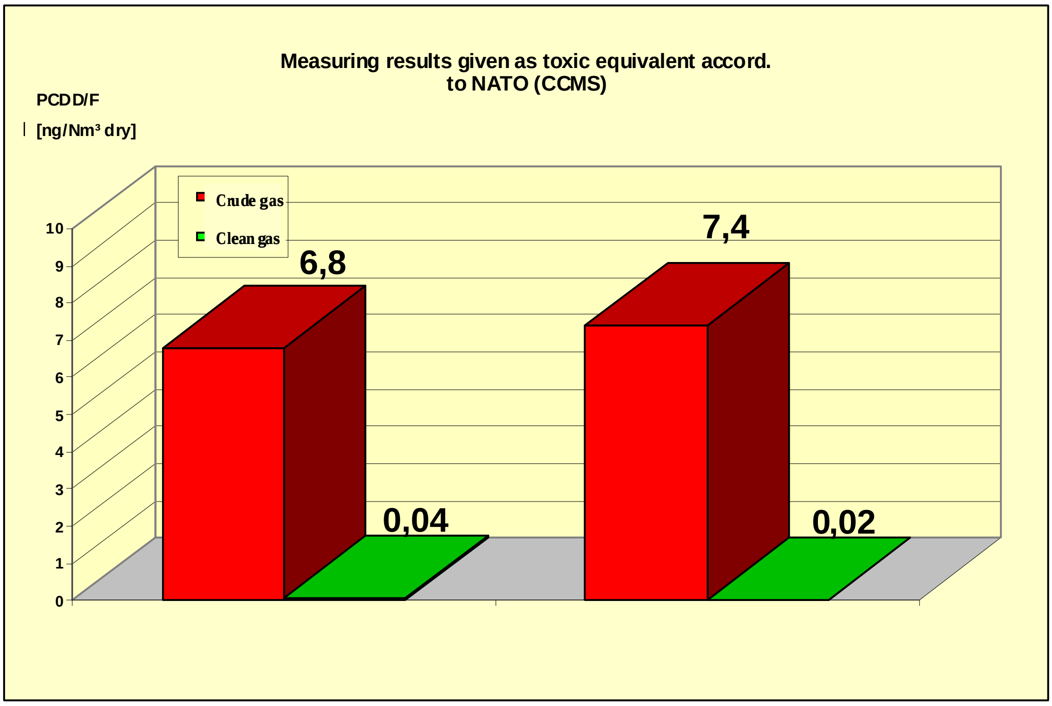
5.3 Adsorption of dioxins / furans

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.
The re-circulation by means of Conditioning Rotor – Recycle Process results among other thing in the following:

- Improved chances of contact of additive powder / crude gas already during fly phase.
- An almost homogeneous distribution of additive powder on the filter bags.
- The quick formation of additive powder containing layers on the filter bags, independent of the current injection of fresh adsorbent (especially important after each cleaning).

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. As far as a mixture of inert material (at least 70 weight %) and activated coke (max. 30 weight%) is used, dust explosions can be excluded. The additive powder already injected for the particle separation and for the protection of filter serves as inert material. With regard to smoulder, constructive measures have to make sure that larger particle deposits within the filter will be avoided. In addition, the gas temperature should be < 160°C.

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 (pic. 13).



Pic. 13: Dioxin/ Furan separation from the off-gas of melting furnaces for secondary aluminium

6 Summary

Fabric filters with particle re-circulation are suitable for the gas cleaning downstream melting furnaces for secondary aluminium.

- Reliable observation of all requested emission limit values for particles, heavy metals, acid crude gas components as well as for dioxins/furans in continuous operation
- Suitable for the installation downstream different types of kilns and for different feedstock
- Correct dimensioning and construction of plant provided, long-lasting filter fabric service lives at high availability can be achieved
- Up-to-date plants grant high availabilities combined with low maintenance
- The application of the Conditioning Rotor – Recycle Process allows the use of cost-effective additive qualities with at the same time good efficiency

The listed positive operating experiences can only be achieved if the aspects mentioned in this lecture will be implemented consistently during the realisation of plants.

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