New process for improved dry scrubbing efficiencies in aluminium smelters

An advanced process for removing and recovering fluorides and particulates from aluminium reduction pot gas has been developed by ABB and tested in a pilot plant prior to full-scale installation. The dry scrubbing system is arranged in two stages, with fresh alumina introduced into the gas flow in a counter-current arrangement at the tail end of the process. An innovative bag pulse system allows the filter bags to be packed more densely in the filter compartment for a more compact construction. The performance of the new dry scrubbing process is significantly better than that of the traditional co-current processes. The process also has potential for dry SO_2 removal with alumina as sorbent.

Traditional dry scrubbing systems used to remove and recover fluorides and particulates from the gases produced by the electrolytic cells in aluminium smelters are based on either co-current (parallel) or cross-current processes.

In the co-current process 1 the adsorbent (alumina) is introduced upstream of a reactor, where it mixes with the gas. Adsorption is achieved through thorough contact between the alumina particles and the gaseous fluoride (hydrogen fluoride, or HF) molecules, and can be enhanced by extending the turbulence and retention time. The alumina is separated from the gas stream in a downstream filter, normally a bag filter.

Recycling of the separated alumina into the gas stream ahead of the reactor improves the efficiency of the system.

The filter stage not only controls the particulate emissions but also acts as an HF adsorption reactor. This combination, termed filsorption, makes some special demands on the design of the bag filter with regard to the gas and alumina distribution as well as the filtercake formation.

The crossflow (cross-current) process 2, in which alumina is transported across the gas stream, utilizes the fluidized bed principle. Dry systems of this type are efficient but introduce extra gas resistance (causing an additional pressure drop) through the necessary gas distribution arrangement and the alumina bed.

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The performance of this process is limited to a certain degree by the HF saturated (enriched) alumina coming into contact with the gas with a low HF level at the tail end of the process. This reduces the ‘driving force’ at exactly that location in the process where it should be strong to ensure very low emissions. Such processes have limited efficiencies when pot HF evolutions and alumina saturation levels are high.

ABBART – the new dry scrubbing process

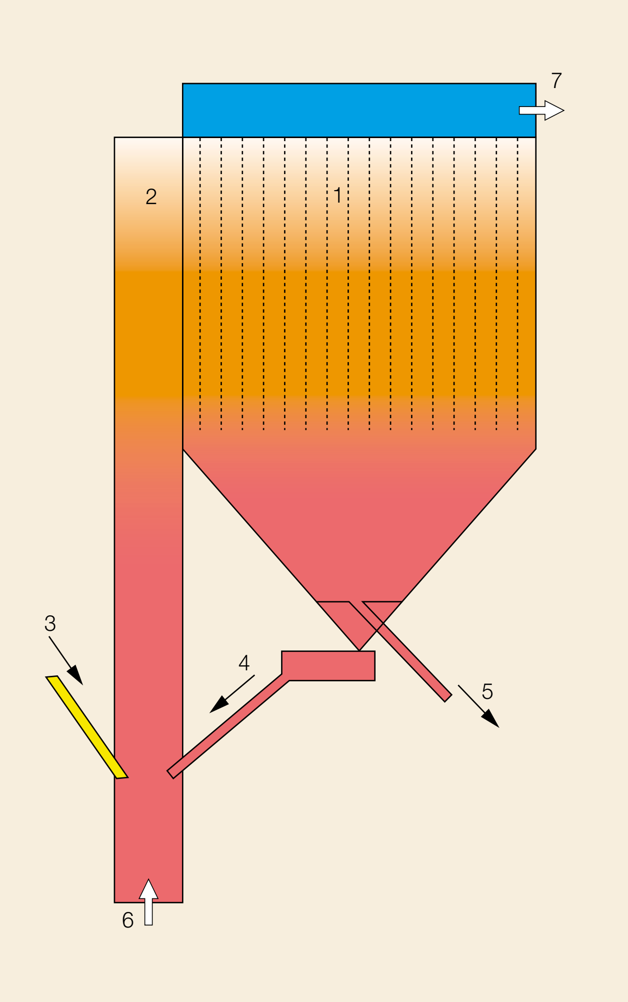
The basic principle of the newly developed and patented process (ABBART) is a two-step co-current process in a counter-current arrangement 3.

The fresh adsorbent (alumina) is introduced into the gas downstream of the reactor stage in the filter or filsorption stage. The full strength of the adsorbent therefore acts on gas with a low HF concentration, as the bulk of the HF load has already been adsorbed by the enriched alumina in the reactor stage. This is achieved by reinjecting the alumina from the filter stage (filsorption) into the upstream reactor stage, resulting in a counter-current flow of the adsorbent.

The reactor stage is designed as a lean phase reactor. The high concentration of adsorbent efficiently reduces the HF concentration prior to the second stage through controlled recycling of the alumina in the reactor stage.

A very important feature is the separation stage, which removes the enriched alumina from the gas stream between the reactor and the filter. This ensures a low penetration of HF saturated (enriched) alumina into the second step, thereby reducing the load of enriched alumina in the bag filter. The result is a reduced pressure drop and lower HF emissions.

The alumina introduced from the filsorption stage into the reactor has almost the same adsorption capacity as the fresh alumina since the capacity used

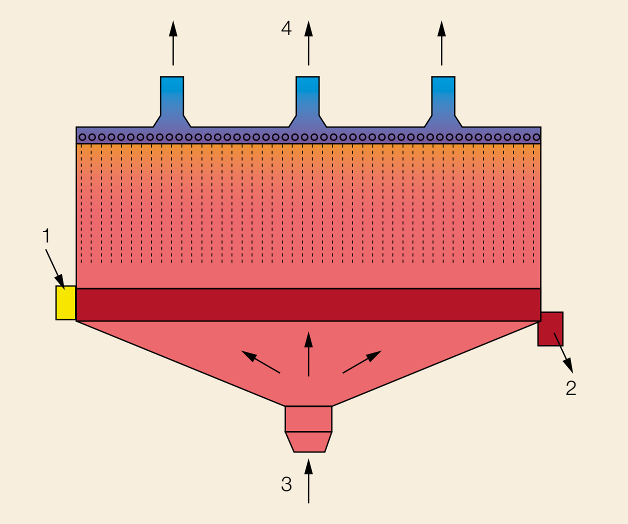


Traditional co-current dry scrubber, in which the adsorbent (alumina) is introduced upstream of the reactor. The separated alumina is recycled through injection ahead of the reactor. **1**

1 *Filter*
2 *Reactor*
3 *Fresh alumina*
4 *Recycled alumina*
5 *Enriched alumina*
6 *Gas inlet*
7 *Gas outlet*

Cross-current dry scrubber. Fresh alumina is transported across the gas stream. **2**

1 *Fresh alumina*
2 *Enriched alumina*
3 *Gas inlet*
4 *Gas outlet*



in the filsorption stage, where the HF concentration is low, is only marginal.

Therefore, the 'driving force' of the new process is considerably increased in the filsorption stage by the adsorption capacity of the fresh alumina rather than by the enriched alumina as in the co-current process. Improved adsorption kinetics and enhanced alumina surface availability in the filsorption stage ensure an optimal mass transfer efficiency for this new dry scrubbing process.

The higher the HF load, the more significant the process improvements become.

Another important feature of the new dry scrubbing process is its ability to handle larger fluctuations in pot gas HF concentrations at stable emission levels.

Compact design – with 55 percent more filtering area

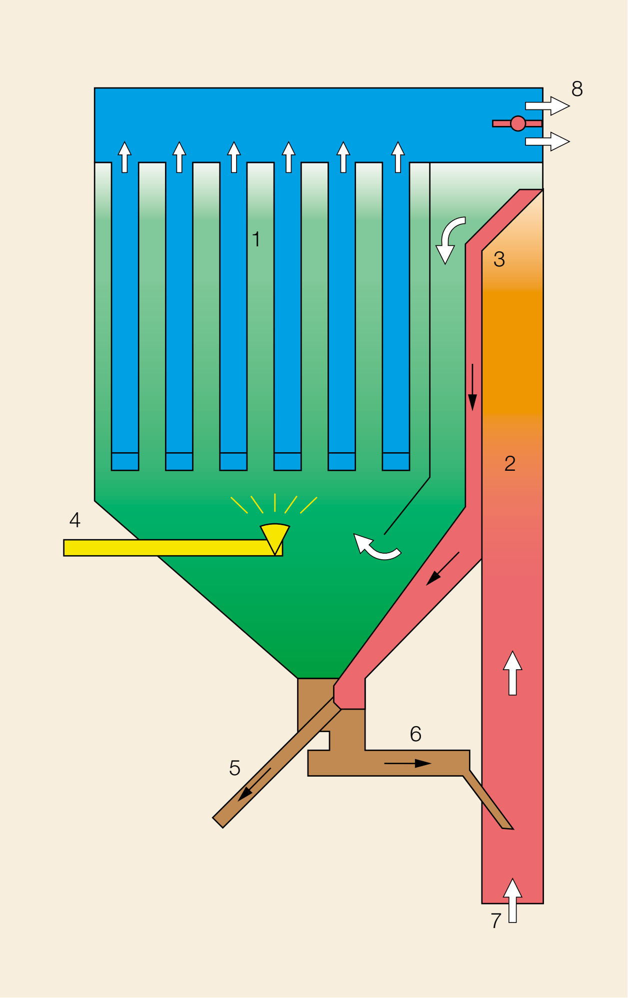
One of the development goals was to design a high-performance system which would also be cost effective. This goal has been achieved: the new integrated two-step system, consisting of reactor, separator and filter stage, is even more compact than the standard co-current design.

The compact design of the new process was made possible by the high efficiency of the reactor and dense packing of the filter bags **4**.

The lean phase reactor features low velocities (10–15 m/s) and a high alumina concentration (100–700 g/m^3). This ensures high HF removal efficiency. The fluid dynamics and gas flow pattern of the system were carefully studied to ensure minimal wear, alumina attrition and scale formation.

As mentioned, the filter or filsorption stage is designed for fresh alumina injection. It is important that this alumina is distributed in the filter in such a way that the filter cake across the filtering surface is homogeneous. Specially developed injection nozzles, positioned according to the controlled gasflow pattern ensure this.

The system also benefits from the latest developments in bag filter technology, such as new pulse valves and nozzle headers which reduce the space requirements. The new concept provides 55 percent more filtering area than a standard-sized filter bag compartment.



ABBART counter-current process. **3**
The new, advanced dry scrubber is arranged in two stages with fresh alumina introduced in the opposite direction to the gas flow from the tail end of the process.

1 *Filter*
2 *Reactor*
3 *Separator*
4 *Fresh alumina*
5 *Enriched alumina*
6 *Recycled alumina*
7 *Gas inlet*
8 *Gas outlet*

Top of a bag filter. Dense packing of the filter bags has led to a compact construction. **4**

Process performance experience

The efficiency of the new dry scrubbing process has been verified during a three-year testing and development period with a pilot plant at a modern prebake smelter **5**. The installed plant consists of a full-size reactor and filter. Gas from modern pots with moderate to high fluoride evolution (HF concentration = 200–250 mgF/Nm^3) is used. In addition, the new process has been in full-scale operation at two smelters since mid-1995 and March 1997, respectively, and is currently being installed at three other smelters, where start-up is planned for 1997/98.

The efficiency of the gaseous fluoride removal improves with the concentration or quantity of alumina in the gas stream. A consequence of this is that the particulate load on the filter bags increases, resulting in a higher particulate emission level. Low HF emissions, combined with low particulate emissions, were therefore targeted. Achieving this would result in a cost-efficient plant design and plant operation.

It is essential with this type of process to separate the two process steps using a high-performance dynamic separator. The minimization of carry-over of enriched alumina from the reactor stage to the filsorption stage ensures high HF removal and low filter drag (pressure drop). The separator design must prevent steel surface wear and alumina attrition.

The separator efficiency observed is greater than 95 percent and attrition of alumina over the total process is insignificant.

HF removal efficiencies

The HF removal efficiencies were tested for several plant operating modes. The results are summarized in **6**.

The performances are shown relative to the performance of a standard co-current process at various HF saturation levels of the enriched alumina (saturation level equals 1.0 for a monolayer of chemisorbed HF on the alumina surface).

For modern pots with higher HF evolutions (200–350 mgF/Nm^3) the relative saturation levels are normally between 0.5 and 0.8. At these levels the new system performs with HF emissions at least 50 percent lower than with the standard process.

The new process therefore has to allow for much higher HF saturation levels without exceeding the normal

Pilot plant installed in a prebake smelter **5**

emission levels (HF < 1.0 mg/Nm^3). This would allow for scrubber operation with a reduced fresh alumina flow. The advantage for a smelter is that a larger proportion of pots can be operated with fresh alumina, allowing a better metal quality and lower costs.

Particulate emissions and fabric material

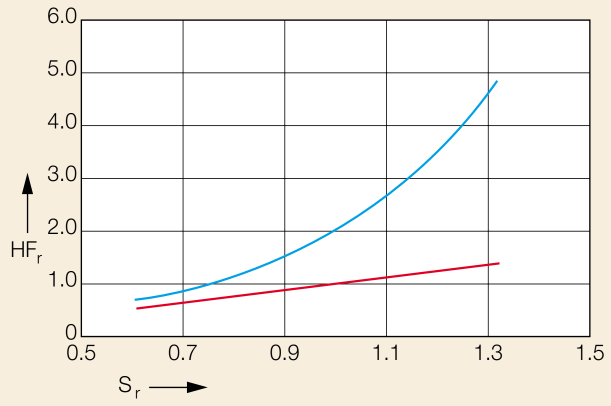
Particulate emissions depend on the filtering velocity, particulate load, filter cleaning modes and fabric material and structure.

Polyester needlefelt **7** – a blend of finer fibers on a base (scrim) made of polyester threads – has been the predominant material for filter bags for some time.

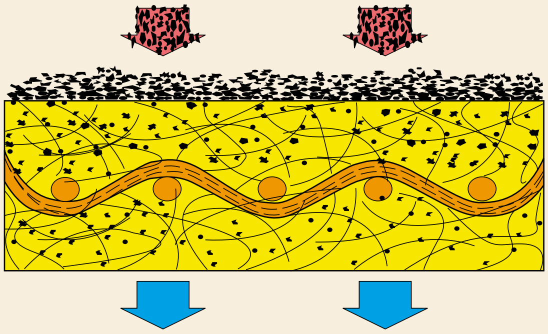
Several filter bag qualities have been tested. Of special interest was the performance of membrane (PTFE-coated) bags in view of their high performance in other applications. Polyester needlefelt bags with different structural fine-fiber design and composition were tested. **8** shows the results of these tests and compares them with the results obtained with a standard needlefelt bag.

HF emission performance **6**

HF_r	*Relative HF emission*	Red	*ABBART process*
S_r	*Relative saturation*	Blue	*Standard process*



Section through a polyester needlefelt fabric with dust layer **7**



Emissions with the membrane bags were low in the early stages of the test, as expected, but soon began to increase steadily with time to levels which are unacceptable for this process. Further tests that had been planned were therefore cancelled.

The reason for this unexpected increase in particulate emission was assumed to be the agglomerating property of the pot fumes combining with the non-agglomerating, abrasive alumina to produce local blinding as well as zones of high velocities and particulate emission.

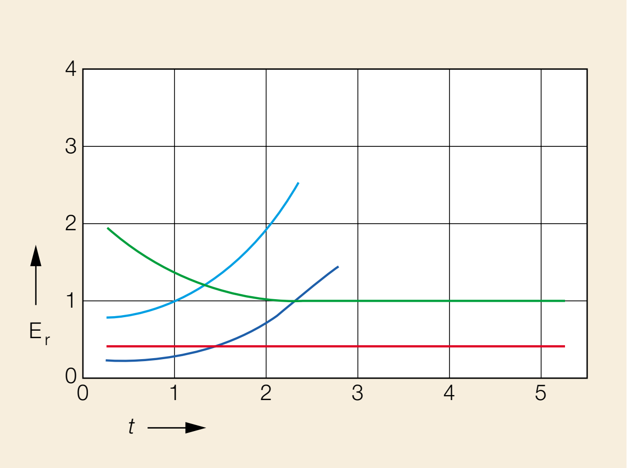
Promising results were obtained with specially designed fabrics that utilized micro-denier fibers. The structure of the fabric has been rearranged to provide a new and better defined filtering layer. Fabric improvements were also incorporated to reduce emission peaks during cleaning.

As **8** shows, unlike the standard fabrics the new, improved fabrics feature a short run-in time or even no run-in time at all, and maintain a low emission level over the test period. Further testing with the new fabrics has been carried out in a full-size plant, and confirms the results obtained in the pilot installation.

Particulate emission optimization

Since the particulates accumulating on the filter fabric and the fumes from the pot gas penetrating the fabric cause an increase in resistance, the bags have to be cleaned periodically. This is done by initiating an air pulse which accelerates the bags away from the cage, releasing the dust as the bags are suddenly retarded. When the pressure build-up in the bags is relieved, the bags return to the cages due to the force exerted by the pressure drop across them. The impact when the bags hit the cages releases dust, which is the main cause of the particulate emission. Emissions between bag pulsing are minimal and insignificant.

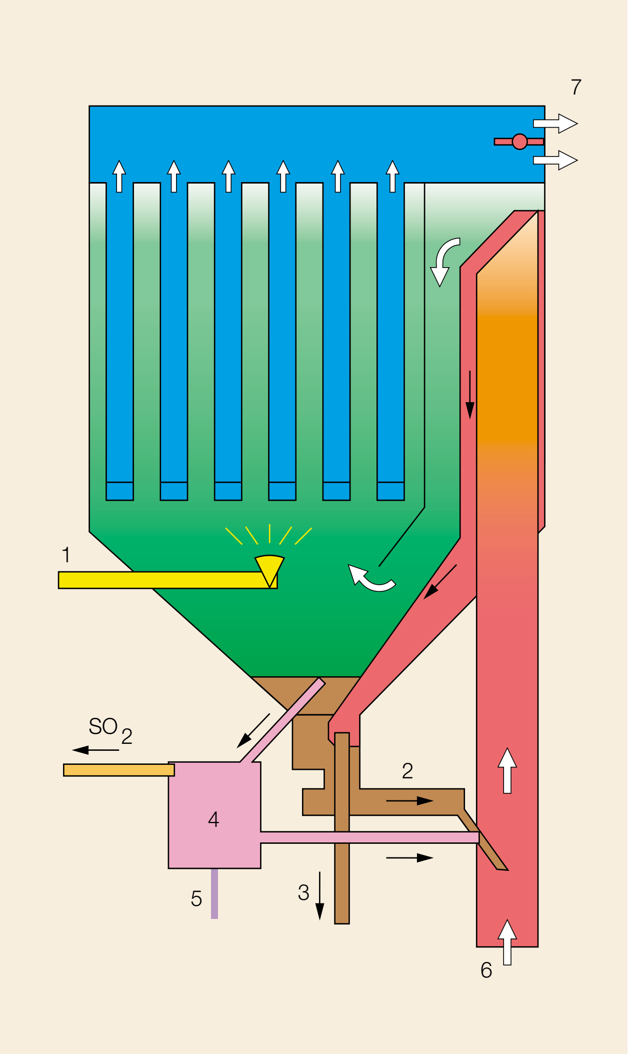
The so-called 'soft landing' principle was introduced to avoid this problem. It involves adjusting the bag pulse pressure and pulse valve opening time at a set



Relative particulate emissions for various fabric materials **8**

E_r *Relative particulate emission*
t *Time (months)*

Green	*Standard fabric*
Red	*Improved standard fabric*
Light-blue	*Membrane fabric no 1*
Dark-blue	*Membrane fabric no 2*



The ABBART process also has potential for dry SO_2 removal with alumina as sorbent. **9**

1 *Fresh alumina*
2 *Recycled alumina*
3 *Enriched alumina*
4 *SO_2 stripper*
5 *Carrier gas*
6 *Gas inlet*
7 *Gas outlet*

Full-size dry scrubber of ABBART design at the ALBA aluminium plant in Bahrain. The scrubber went on line in March 1997. **10**

bag pressure drop and pulse frequency to ensure low impact when the bag hits the cage, resulting in minimal dust emission. This optimization has resulted in a considerable reduction in particulate emission (of the order or 50 to 90 percent), with demonstrated results of below 1.0 mg/Nm^3.

Potential for dry SO_2 removal

It is a well-known fact that SO_2 adsorbs on alumina [1]. Tests have shown that adsorbed SO_2 will desorb in the presence of HF as adsorbed SO_2 is replaced by HF on the surface of the alumina.

In a two-step process in which the HF is removed or reduced to insignificant concentrations in the first step, the SO_2 may be adsorbed in the second step.

The ABBART process shown in **9** is ideal for such a combined process. The SO_2 is adsorbed in the filter stage. Afterwards, the SO_2-rich alumina is passed through a stripper which desorbs the SO_2 into an SO_2-concentrated gas. The regenerated alumina is then used in the reactor for HF removal and recovery.

The SO_2 is stripped from the alumina by means of a heated carrier gas, controlled to desorb only SO_2 without desorbing the more strongly bound HF molecules.

The SO_2-rich gas can either be processed into valuable products or made to react with lime to provide gypsum suitable for either commercial use or safe disposal.

Preliminary investigations show that an SO_2 removal efficiency of > 90 percent is achievable with the new system. Compared with traditional and current technology for wet scrubbing systems, the new system therefore has a significant potential for cost reduction.

Reference

[1] W. D. Lamb: SO_2 in aluminium reduction-cell dry scrubbing systems. Journal of Metals, Vol. 2 (1979) 32–37.

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