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INNOVATIVE DISTRIBUTED MULTI-POLLUTANT POT GAS TREATMENT SYSTEM

Geir Wedde, Anders Sørhuus, Odd Bjarnø
Alstom Norway AS, Drammensveien 165, 0277 Oslo, Norway

Pot Gas Treatment, Emissions, Energy Recovery

Abstract

Gas Treatment Centers (GTC) are traditionally arranged in the courtyard between pot rooms and handle vast quantities of pot gas (3- 4 million m3/h) in a large number of filter compartments (15-30) with demanding space requirements and challenging control of operation.

Arranging the gas treatment in decentralized installations as Decentralized Distributed Scrubbers (DDS) would obviously save on duct work, alumina handling, storage and civil work. In addition Alstom's DDS integrates silos, heat exchangers, scrubbers, fans and stack into an extremely compact and efficient multi-pollutant control and recovery technology with incomparable footprint. The close integration with pots improves pot gas collection and simplifies the alumina distribution to pots. Module based design allows for short delivery time and early start-up. This paper discusses and reviews the benefits and mitigation of the technical challenges offered by the DDS solution.

Introduction

New greenfield aluminium smelters and brownfield smelter amperage increase or expansions have increasingly demanded larger gas flows to be handled by gas treatment systems leading to an economical challenge as well as space (footprint) issue.

Gas flows from sections of pots are traditionally handled by Gas Treatment Centers (GTC) arranged in the courtyard between pot rooms. The size of GTCs has dimensions of a large office buildings being up to 150 m long and 30 m wide and rise to levels of 30 m. For operational flexibility and gas and alumina flow considerations the GTC is made up of a number of identical compartments that operate in parallel. The number of compartments could be as many as 30 or above which may be challenging to tune, operate and to detect failures or faults among the individual units.

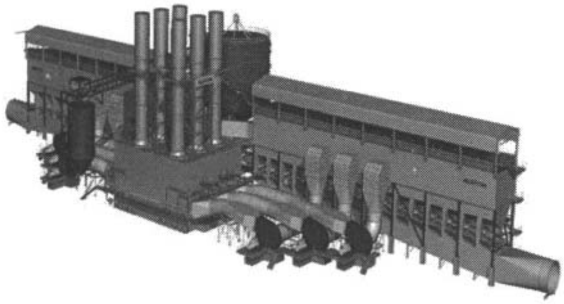

Figure 1: Gas Treatment Center (GTC) for modern pot lines

It is obvious that the GTC size and footprint must fit within a smelter requirements and practical arrangement and it seems that this limit has been reached. Alstom has developed a solution that divides the traditional GTC into smaller sub-centers that are distributed along the pot rooms. These small plants are called Decentralized Distributed Scrubbers (DDS - patented).

Decentralized distributed scrubber (DDS)

Gas treatment plants for pot lines must satisfy the stringent requirements that are forced on them through the continuous production process that governs the aluminium electrolysis. This means a 24/7 operation year round including high equipment redundancies.

DDS lay-out and arrangement

The difference between the GTC and DDS lay-out in the courtyard between two pot rooms is illustrated in figure 2. The DDS has been laid out close to the pot room walls and connected to a section of pots. A number (12) of identical DDS consisting of equal pot ducting systems, filters, fans and alumina (fresh and enriched) handling systems are shown.

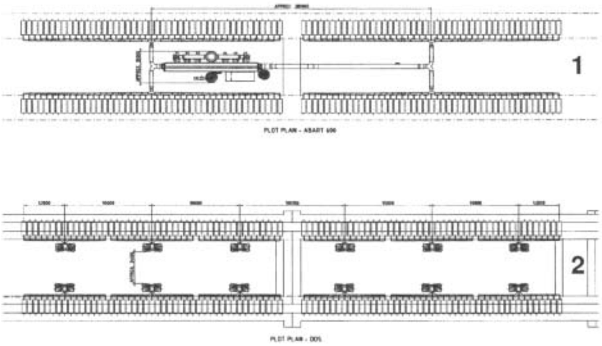

Figure 2: GTC lay-out (1) and corresponding DDS lay-out (2)

The illustrated GTC handles pot gas from a total of 180 pots arranged in two pot rooms with 45 pots in each half of the pot room on both sides of the cross-over passage way. The GTC is designed to operate with a total pot gas flow of 2.5 million m^3 per hour. A typical arrangement of DDS would be to handle gas from 15 pots (~210,000 m^3/h) in each DDS which means a total of 12 small gas treatments plants. This includes allowance for running 2 pots simultaneously on forced draft (~24,000m^3/h) for each section.

Arrangement and design of a DDS

The smallest gas treatment center should include a minimum of 2 reactor/filters and 2 exhaust fans with sufficient redundant equipment for independent operation. Any other combination of number of pots and compartments is readily adaptable with DDS small compartment sizes and adjustable bag lengths. An arrangement of a DDS is shown in figure 3. Each of the two units is a fully equipped Abart [1] dry scrubber including fresh and enriched alumina storage, fresh alumina metering and transport, reactor/filter, alumina recycling feeder, fan and stack.

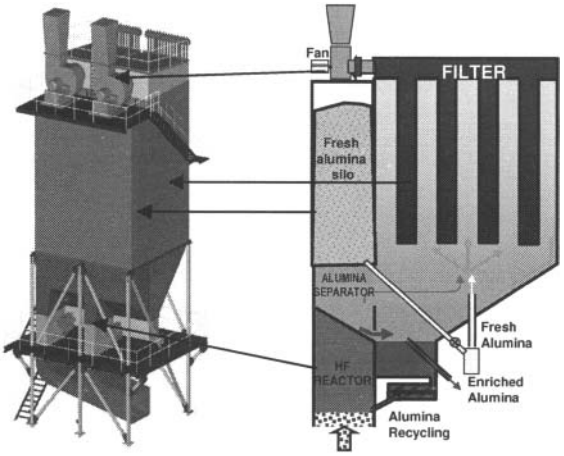

Figure 3: Arrangement and design of a DDS plant

The adaption of fans on top of the fresh alumina storage requires additional stiffening and vibration pads. The mini-stacks are equipped with sound absorbers both at fan inlets and in mini-stacks.

Benefits of DDS

The benefits of gas treatment plants arranged as DDS are many but also challenges and some disadvantages are obvious. These are analyzed below with the assumption that fresh alumina is stored in one central silo and the fresh alumina requirement for the DDS is achieved through dense phase transport up to the individual DDS.

Foot print

There is a substantial reduction in foot print area by implementing 12 DDS plants rather than one GTC (figure 2). One DDS unit of 4 compartments takes up approx 90 m^2 of area in the courtyard and 12 DDS will then occupy nearly 1100 m^2 while a GTC would cover about 2300 m^2 which is more than double of the DDS. This saving in space or foot print is of significant value for the smelter.

In addition the flexibility in the location of each DDS in the courtyard allows for an increased optimization of space and pot room and utility building lay-outs

Alumina storage and handling

Integrated with each Abart filter compartment in a DDS is fresh alumina storage of 25 tons. This capacity reflects close to 2 days consumption of alumina of the pots.

From the storage of fluoride enriched alumina in the filter compartment hoppers the enriched alumina may be fed directly to the pots through an Alstom Alfeed pot feed system [2] or other feed systems on the market. This saves intermediate silos and alumina transfer points that tend to increase segregation possibilities of the alumina and disturbances of pot operations.

The hopper capacity for stored enriched alumina is about 3 tons per compartment and a direct by-pass from the fresh alumina storage to the pot feed system is available ensuring alumina feed to pots at all times.

Recycling of enriched alumina within one compartment is achieved with individual feeders with adjustment control.

Performance enhancements

Each compartment has individual control of gas flow by a dedicated exhaust fan; fresh alumina feed and enriched alumina recycling through frequency controlled drives. Each compartment should run with the same flows and feeds and with the above features DDS has the possibility to individually fine-tune each compartment. This allows the DDS system to easily and accurately achieve equal gas flow with equal alumina feed through each compartment. Each DDS compartment utilizes independent bag cleaning control which allows simultaneous tuning of pressure drop, flow and particulate emission (particulate emission is directly related to pressure drop of a filter).

The direct fresh alumina feed from silo into the gas stream ensures constant feed without any surges and reduces stops for cleaning of airslide systems.

Overall the DDS has the potential of reduced emissions through optimized adsorbent utilization and enhanced plant stability level.

The DDS is designed to utilize multiple bag lengths, but 8 m bag length is preferred for improved cost efficiency.

Power consumption

DDS represent a significant saving in power consumption of the gas treatment installations for a smelter. Pot room ducting, cross-over ducts, filter to stack ducts and stack are additional ducting with additional resistance of a traditional GTC. The reduced pot gas pressure drop for a DDS equals about 15 % of the total GTC gas pressure requirement which is a 15 % reduction of the power consumptions of the main fans.

Steel weight

It is easily seen that the duct system has been substantially reduced as the DDS are located close to the pots and use smaller and identical pot duct sections. Ducts from GTC filters to the exhaust fans and the large stack are eliminated. As DDS integrate the required silo capacities, both the fresh and enriched alumina silos can be eliminated. One may expect an increased weight of the DDS filters due to the increased total number of compartments; however, DDS with 8 m long bags has the same weight per unit of gas flow as the Alstom standard GTC equipped with 6 m bag length. With the arrangement as seen in figure 2 the reduction in steel weight of DDS is in the order of 30 % of a comparable GTC.

Equipment scope

There is a significant saving on alumina transport and silo fluidization, but an increase of alumina feeders. Although GTC has only 6 large fans compared to 48 fans for DDS, the GTC fan cost is about 4 times that of DDS. Filter bags and cages are reduced by the DDS by approx. 20 % because of extended bag length.

Electrical items and instruments

As each DDS will have to be electrified from a central source, number of power and instrument cables will increase substantially for a DDS arrangement. Motor starters, instruments, plant switches and signals, are proportional to the number of filter compartments which may amounts up to 20 % extra for the DDS system.

Although the power tension required is LV - low voltage (< 460 V) and that the cabinet etc for each DDS is located in a common cubicle that can be mounted and furnished in a work-shop and shipped to site, the electrical scope may be more than twice that of the GTC.

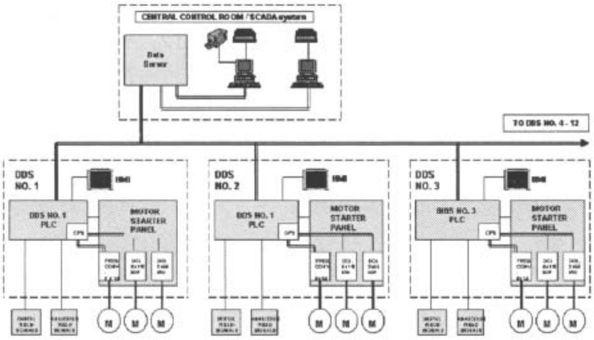

Figure 4: Basic DDS E&I topology

However, DDS simplifies total electrical lay-out and is exampled in figure 4. A GTC will have substations for both MV and LV, as the main fans normally require MV. MV can be removed, and a number of identical cubicles for each DDS installed.

It is reason to believe that the extra electrical scope of the DDS can be significantly reduced by working close with the smelters utilizing and incorporating the existing electrical system lay-out.

Manufacture, transport and erection

The size of a DDS compartment is fulfilling the requirement on regulation of transport on roads. DDS is suitable for offsite and offshore pre-assembled, with manufacture in work-shops and transport to site.

Cost efficient production of filter panels, hoppers and tops utilizing automatic, robotic manufacturing systems has been demonstrated with success for other products as Alfeed. This allows fast erection in lay-down areas or directly on site as seen figure 5.

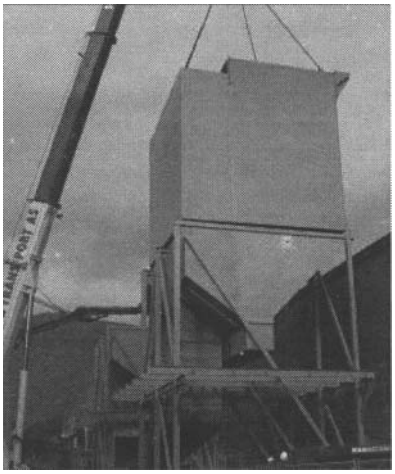

Figure 5: Installation of work-shop erected DDS modules

Erection of several DDS units can be achieved simultaneously and independently which is not the case for a GTC where many items are dependent on each other as for erection of filter compartments, alumina handling to and from these compartments, stairs and platforms, and electrical and instrumentation.

Further benefits

Civil work for a GTC installation is a significant part of total cost. The foundations for the heavy silos, filter compartment support, main fans and stack are extensive compared with the simpler arrangements for the DDS.

For smelters with pot line expansions DDS represent a simple and unique opportunity for stage wise implementation as the system connects to a smaller number of pots. The bolted design eases the installation in an operating smelter as magnetic field strength complicate welded construction.

There are projects where the GTC falls on the critical path of the smelter erection sequence. The DDS will allow quick and independent erection and potentially early start-up of metal production.

Challenges of DDS

There are challenges to the DDS solution that sometimes would become opportunities but also a re-think of the smelter operation may facilitate all the benefits that have been addressed above.

Pot gas temperatures

As the DDS is closer to pots it should experience higher gas temperatures (15-20 °C) than the GTC. It is well established that pot gas temperatures affect the performance of the dry scrubber and in order to meet current requirements the gas temperature at scrubber inlet should be 115-120 °C [3]. This requirement means that the DDS may need additional cooling upstream the filter compartments. If dilution air was to be used a significant quantity of air has to be added and the cost efficiency of the DDS would suffer.

Integration of heat exchanger

Alstom has developed heat exchangers operating on the pot gas upstream the filters [4]. Improvements on this technology are ongoing and a heat exchanger integrated (IHEX) into the inlet duct/reactor of the Abart filter compartment has now been realized. This allows significant savings on the heat exchanger system as support steel, stairs and platforms, and the damper arrangement is combined with the DDS design as seen in figure 6.

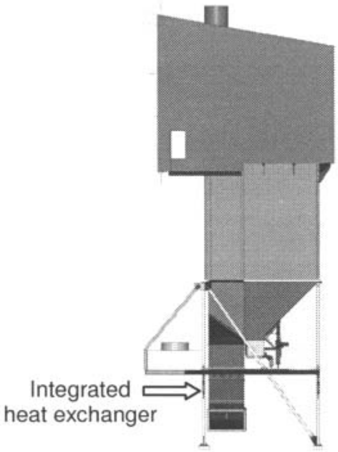

Figure 6: The integrated heat exchanger (IHEX) for DDS

This innovative solution reduces the pot gas temperature to any desired practical levels (90-120 °C) depending on the purpose of the heat exchanger whether it should only cool the pot gas ahead of the gas treatment plant and /or to recover waste heat for use inside or outside the smelter. The additional 15 (- 20) °C temperature level of the pot gas entering an DDS means a significant contribution to higher value heat (exergy) of about 50 kW/pot. For a 180 pot smelter this amounts to 9 MW in addition to a traditional (GTC) heat recovery potential with IHEX of 15-20 MW.

Operation redundancy

The DDS is designed to utilize multiple bag lengths, but 8 m bag length is preferred for improved cost efficiency.

For special purposes and increased flexibility as when the N-1 redundancy principle applies the DDS can be equipped with shorter bag length (5-7 m) which will increase the number of compartments. Connecting pair-wise DDS will add further flexibility and with frequency operated motors of main fans one compartment can be taken off-line with only a slight reduction in total gas flow from pots.

Even more gas flow capacity is achieved when the HEX is designed with some over-capacity that allows further cooling of the gas.

Therefore the combination of size and number of compartments and with a heat exchanger the DDS solution has sufficient gas flow capacity to satisfy traditional redundancy needs of a smelter.

Fluidization of filter hopper and mini-airlifts and pot feed system is generated by one blower/fan only using air from the pot room plant air lines as stand-by. It is also preferable to use plant air instead of installing dedicated air compressor and dryer equipment for bag cleaning air needs.

Feeders, recycling units and main fans are easily accessible in the DDS and spare units can be stored at the smelter for fast replacement of broken units.

During situations of "sick" pots where pot gas temperatures increases and fume evolutions are enhanced the HEX will achieve improved performance and cooling as the temperature differences of pot gas and cooling water increases. Short term high HF evolutions can be controlled with increased fresh alumina feed.

Cover material for pots

Many smelters and pot technologies use enriched alumina and mixed with bath for covering and dressing pots. For DDS this can be facilitated by inter-connecting several pot feed sections from several DDS units would allow these DDS to run with slightly higher feed equal to the cover material needs. The remaining DDS will have to be slightly starved of fresh alumina feed but the overall emission level from DDS will not be affected.

The additional flow of enriched alumina could be extracted from the pot feed system at an appropriate location into an airlift feeding a cover material silo. Optionally one can feed a tanker with cover material and feed the silo in batches which would then overcome the high capacity discharge needs from silo to pot tending cranes.

Emission monitoring

The DDS is prepared for the installation of HF and dust measuring equipment, easy accessed from the filter top. To reduce the number of monitors required a system for extraction of gas from each mini-stack into a laser based analyzer has been developed.

Emission dispersion

Discharge of treated pot gas from GTC stacks would require stack height level above pot room roof louvers to meet stringent emission requirement through emission dispersion modeling. For DDS it would have been detrimental to its design simplicity to have enforced same stack heights as on the GTC.

As DDS introduce multiple stacks at locations across the pot line the dispersion of the emissions is significantly improved and DDS emissions can be released at lower levels. The emission through the pot room roof is of similar concentration levels as from the DDS mini-stacks and it would be natural to use similar discharge height level for the mini-stacks.

Magnetic fields

The DDS is located closer than a GTC to the pot room and is therefore exposed generally to higher magnetic field strength. This has to be considered especially regarding electronic equipment.

The main fans, however, are located on top of the DDS which increase the distance to the source (electrical bus bars) of the magnetic fields. It has been calculated that the field strength at the DDS main fans is similar to the one at the GTC main fans.

The DDS is normally made as a bolted solution, which means considerably less welding and ease of erection if the construction has to take place in the magnetic field of an existing operating smelter.

Multi-pollutant gas treatment

More often SO_2 scrubbing is required for aluminium smelters, in particular the large mega-smelters where SO_2 emission may have a detrimental impact on the local ecology.

Wet SO_2 scrubbers are used which absorb SO2 into an alkali solution and smelters operating at coastal areas would benefit from using seawater as the absorbent [5].

To accommodate the DDS principle of simplicity and modularization a SO_2 scrubber design has been developed and on-going tests will confirm the performance which are targeting levels that exceed current SO_2 scrubbers for GTC

Operational experiences

Experiences with DDS have been obtained since 2007 where 2 DDS plants (figure 7) were installed at an aluminium smelter. Each DDS consists of 2 compartments and handles 115.000 m^3/h. The two DDS are interconnected to achieve highest flexibility. Fresh alumina is fed to the four integrated silos in the DDS by an airslide system running from an elevated existing silo. The enriched alumina is fed to 2 pot sections.

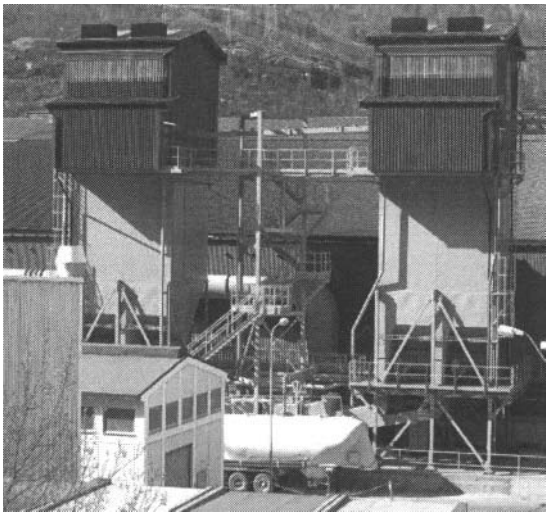

Figure 7: Operating DDS installations

Emission performance

Particulate emissions has been followed up and monitored regularly as testing of filter bag materials is part of an agreed cooperation with the smelter.

The performance of "standard" polyester needle felt filter bags is demonstrating consistent low particulate emission at about 0.9 - 1.1 mg/Nm^3, and the particular test campaign below (figure 8) shows emissions during pulse air cleaning of the filter bags reaching about 12 mg/Nm^3 as a peak value and reducing to a value close to zero between each cleaning action. The total emission over several cleaning cycles is 1.04 mg/Nm^3

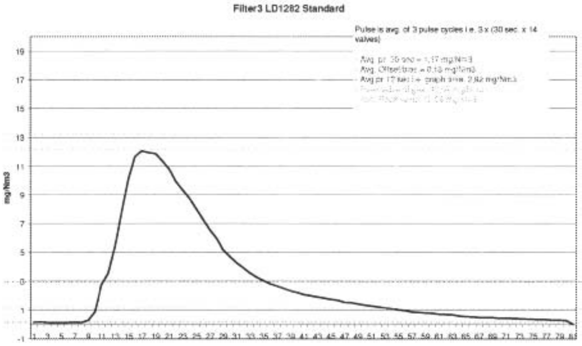

Figure 8: Particulate emission peaks during pulse cleaning of "standard" filter bags.

Filter bags with enhanced micro-denier fibers embedded in the outer filtration surface achieve an exceptionally low peak emission consistently lower than 3.0 mg/Nm^3 as seen in figure 9. The total particulate emission is reduced to only 25 % of the "standard" bag emission to as low as 0.25 mg/Nm^3.

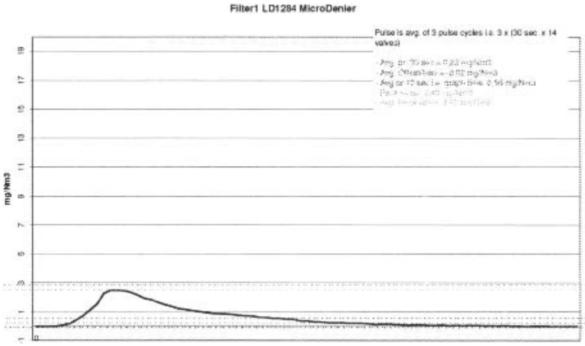

Figure 9: Particulate emission of "micro-denier" filter bags

Two test campaigns using manual test equipment, of emission of gaseous fluorides (HF) has been recorded at an average level of 0.26 mgF/Nm3 with F-content of the enriched alumina at 1.80 %.

For low HF concentrated pot gas with 1.15 % F-content in enriched alumina the HF emission level was as low as 0.04 mgF/Nm^3.

Conclusion

The principles of centralization do not always reduce costs and ease the operation of a system. The DDS solution as distributed gas treatment plants located close to the pot room and handling gas from a limited number of pots (10- 30) has many advantages and benefits that should be explored further by the aluminium industry.

The reduced cost and power consumption in addition to the reduced foot-print of 50 % and the increased potential of waste heat recovery would obviously make this industry more competitive.

DDS has flexibility and operational performance that will meet future emission requirements. Particulate emission levels at only 1/10 of traditional level is achieved by applying filter fabric made with micro-denier fibers.

Incorporating a SO_2 scrubber in the DDS solution makes it a cost efficient multi-pollutant gas treatment technology.

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