The Application of Extended Surface Filtration Bags in Gas Treatment Centres

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1. Abstract

The increased requirements for alumina dry scrubbers in primary aluminium smelters has put pressure on operators, engineers and technology suppliers to find new solutions to increase the capacity of dry scrubbers. A main constraint is the limited ability to increase flows due to the ever-present limitation that dry scrubbers are seldom installed with extra capacity for future requirements. One solution that has provided a cost-effective increase in dry scrubber capacity, is the use of so-called extended surface filter bags (ESB). These bags are commonly known as ‘star bags’. The ESB bags are constructed with at least twice the surface area of cloth than standard bags and because of this they can operate at lower pressure drops. The gain in pressure drop can also be passed on to the fans to allow them to draw more air through the system. In this paper the authors provide an independent update on the application of ESB bags in alumina dry scrubbers in primary aluminium smelters. There are now multiple dry scrubbers equipped with these kinds of bags. The paper also goes into the principles of the working of extended surface filter bags to demonstrate where the benefits come from. Regarding the implementation, the paper highlights what preparations are required and once installed, show a successful application of a new generation of ESB bags installed in a gas treatment centre (GTC) in Europe.

Keywords: Gas treatment center, alumina dry scrubber, extended surface filter bags, star bags, GTC upgrade.

2. Introduction

Going back in time, the first patent granted that resembles a fabric type filter bag was to J. T. Jones in 1852. This was a single filter bag of 8 feet diameter and 70 feet long and it was used to filter zinc dust from process gases. It was around 1900 that the filter bag shapes transformed to the shape that we know today, which is a cylinder with a diameter of about 5 inches (127 mm). Interestingly, the first cleaning method was the shaker type since it is so simple to use. Shortly after that the reverse air principle found its way into gas filtration. Between 1910 and 1950 there were very few developments in fabric filter equipment due to the overwhelming use of electrostatic precipitators. Only after the 1950’s this changed when new fabrics were derived from petroleum products whereby the new fabrics provided for properties that made filter bags resistant to higher temperatures and acidic conditions. Interestingly, it was not until 1957 when the pulse jet type cleaning was introduced in dust filtration systems [1].

Concerning alumina dry scrubbing technology, the first patent was granted to Robert T. Pring of the Wheelabrator Company in 1956. That same year Séraphin Lacroix of Pechiney was granted a patent on a similar process. However, it was Alcoa that made the most advances in the actual design of an alumina dry scrubber through their research programs. Their development commenced in 1957 and resulted in a model R173 where activated alumina was injected upstream to a baghouse. In 1962 Alcoa introduced the R252 scrubber in the Badin smelter which was the first fluid bed type scrubber. From the R252 model the R398 model was derived and this was tested first in the smelter in Warrick in 1967. Three years later a patent for the A398 technology was granted to Clayton C. Cook and Lester L. Knapp and the first industrial units were installed in the Badin plant. The R398 was now proven and became the A398 model, which is essentially the same A398 technology that is still in use today with some modern tweaks. In a similar manner, the first injection type alumina dry scrubber technology as we know it today was patented by Wolfgang Muhlrad of Air Industries (now: Fives Solios). The first industrial units were installed in INTALCO in 1973 and today are still in operation. Around the same time, Fläkt (now: GE Power Norway) installed its first alumina dry scrubbers in the smelter of Granges in Sweden [2].

Filter bag fabrics were initially made from closely woven cloths of cotton, wool, flax, or other fibrous textiles. As mentioned earlier, in the 1950's products derived from petroleum led to the creation of new, man-made fabrics that has certain advantages over natural materials. In GTCs the material of choice is almost exclusively polyester. In 1941 British scientists Whinfield and Dickson patented PET or PETE which forms the basis for production of synthetic fibers such as polyester. It was first manufactured by Imperial Chemical Industries (ICI) and in 1946 DuPont bought all legal rights from ICI. In 1950 DuPont manufactured another polyester fiber, which they named Dacron followed by Mylar in 1952. Polyester was first introduced to the American public in 1951 as the magical fabric that needed no ironing. During that period these new fabrics also started to find their way into industrial applications such as the manufacturing of filter bags [3].

For all those years, the shape of the filter bag had fundamentally not changed. If a large surface area was required for filtration, then this was created by using many rows of cylindrical bags to keep filtering velocities in range and to properly remove solids from gases. However, the need to upgrade existing filter houses was a real challenge and often required the addition of new filter compartments. This aspect drove the development of what eventually became the extended surface filter bag (ESB). The star-shaped model filter bag was certainly not the first model to increase the effective surface of a single bag, but it is proven to be one of the most reliable ones.

The first extended surface filter bag was a rigid Polyimide (P84) star-shaped needled felt bag, developed and patented in Germany by Klaus Schumann in 1993. This was a cage-less, star-shaped filter bag for hot gas applications whereby the rigid and self-supporting structure was accomplished by applying a vitrification process at 260 °C [4]. However, despite the superior filtration characteristics, the filter elements were unable to meet the 3-year life warranty because of premature flex fatigue. This meant the bag needed a cage to give it the right strength. Later in 1994 the extended surface filter bags, as we know them today, were patented in the US by Klaus Schumann and assigned to Albany International [5]. The shape of the bag looked like a star and from here onwards Albany continued to use this in the name for the bag: Star Bag™. The use of cage did allow for practically all known filter fabrics to be used, including polyester. The early applications were in the cement industry, foundries and others, mostly in shorter length up to 3.6 meter in US and Mexico, but later also e.g. in Europe and Australia in lengths up to 6 meter and more [4], [6].

At this point in time there are also pleated type filter elements in the market. The ESB technology referred to here is a so-called bag-on-cage technology as opposed to a pleated element. The pleated element design uses different media, different top and bottom construction polymers and, importantly, does not use a cage. Whilst the pleated element design has been applied to some aluminium smelter applications (ref. INTALCO), its success has been limited.

The extended surface filter bag made its introduction to the Aluminium industry in 2002 when Albany completed a conversion from conventional bags to extended surface filter bags in a fume treatment system at Metalcorp Recyclers in Gladstone, Queensland. In total 288 bags were requirement to go beyond. However, one does observe the ability of the fans to consistently stay above target in the summer when the requirements are the highest and the fans typically suffer from the decrease in gas density as a result of higher off gas temperatures.

Irrespective, it is observed that fan capacity is increased now that the bags are replaced. Because of this, engineers are evaluating whether it is feasible to add high draft systems to the potline. This would lead to another step change in emissions reductions in the plant.

9. Conclusions

Filtration technology is very old and goes back to early industrialization. There have been many innovations but some make a step change and extended surface filter bags can be considered one of them. The introduction of extended surface filter bags in filter units are an example where upgrades have become much easier and more powerful than otherwise was the case. The development of extended surface filter bags shows again that a good technology takes time to find its way to industrialization, espacially in the primary aluminium industry. But adaptation is fast as the references show us and the ongoing trend teaches us that there is a general accpetance that these filter bags come with real benefits and can be justified, and importantly, deliver the envisioned results. The first introduction of extended surface filter bags in GTCs and FTCs should start in time and require the engineers to do the homework first. The steps of implementation are described in this article. This includes conducting onsite quality inspections that have been proven to make a difference and contribute to the succes of the project.

The actual results from one GTC conversion are shown as an example and this has been a good succes for this smelter. However, it is known that other smelters see the same positive impacts when they do their evaluations. This will continue to be a the driving force for future projects for further introduction of extended surface filter bags as we believe that we are only at the beginning of the use of this technology.

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11. Symbols

A .... Surface of a filter bag (m^2)
ΔP .... Pressure drop (Pa)
$\Delta \rho$ .... Difference in density between air entering the stack and ambient air (kg/m^3)
δ .... Thickness of the cake (m)
D_p .... Diameter of a nominal particle (m)
ε .... Porosity or void fraction (-)
f_p .... Friction factor (-)
g .... Acceleration of gravity (m/s^2)
H .... Height of the GTC stack above the elevation of pots (m)
K_c .... Specific resistance of cake (-)
K_f .... Specific resistance of fabric (-)
μ .... Viscosity of the fluid (air) (Pas)
Q_m .... Mass flow of particles (kg/s)
ρ_f .... Density of air (kg/m^3)
ρ_p .... Real density of the particles (kg/m^3)
Re_p .... Reynolds number related to particles (-)
v_s .... Superficial gas velocity (m/s)
w .... Specific weight of cake on filter bags (kg/m^2)