Light Metals 2013 *Edited by: Barry Sadler*
TMS (The Minerals, Metals & Materials Society), 2013

LATEST FILTER DEVELOPMENTS INCREASING EXISTING ALUMINIUM SMELTER GAS TREATMENT CENTRE CAPACITY AND REDUCING EMISSIONS

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Keywords: Dust Collector, Emission Control, Fabric Filter, Capacity Increase, Baghouse Retrofit, Filter Efficiency, Gas Filtration, Pressure Drop, Gas Treatment Centre, Ad-Flow

Abstract

Extended surface filter technology has been used in aluminium smelters around the world to increase the dust collection and fluoride scrubbing capacity of existing GTCs. This has provided an alternative to major capital equipment upgrade and lowered the production cost per tonne of aluminium where GTC capacity limitations were restricting production.

As production rates in the smelter increase with capacity creep, so too does the GTC operational temperature. While the proper application of extended surface filters can help compensate for the reduced alumina reaction rate at higher GTC operational temperatures, some smelters increased production demands are now pushing the GTC operation temperatures beyond the limits of the standard polyester filter media. Alternative traditional high temperature filter media is cost prohibitive, and this change in the aluminium smelting industry has created a new cost/solution gap in the market of commercially available filter media.

This paper summarises the success of the extended surface filters, and the development of a new and cost effective higher temperature filtration media. This media, when used in conjunction with extended surface filters, will address both increasing GTC operational temperature and the demand for greater capacity from existing GTCs without the need for costly capital equipment upgrades.

Introduction

Introduction To Aluminium Reduction Potline Fume Treatment

In the aluminium reduction process, primary alumina is injected into the fume from the electrolytic cells. The alumina reacts with the fluoride gas emitted from the cells forming aluminium hydroxyfluoride (equation 1) and aluminium fluoride (equation 2) [1]. The reacted alumina dust is then fed back to the electrolytic cells where the fluoride is recycled in the electrolyte.

$$Al_2O_3+2xHF(gas)+(15-2x)H_2O \rightarrow 2AlFx(OH)_3\text{-}x\bullet 6H_2O \quad (1)$$
$$2AlFx(OH)_3\text{-}x\bullet 6H_2O \rightarrow 2xAlF_3+(45-3x)H_2O+(3-x)Al_2O_3 \quad (2)$$

It is important to note that this formation of hydroxyfluorides is an irreversible chemical reaction under typical dry scrubbing conditions [2]. While the rate of this reaction is independent of the HF concentration in the gas, it is highly dependent on the alumina specific surface area, the gas turbulence and contact time, the gas relative humidity, and the gas temperature.

As production rates in the smelter increase, there is a greater load placed on the gas treatment system, and a greater need to modify the gas treatment system to retain emissions below licensed limits. Increased production rates result in a compounding detrimental effect on the gas treatment system in both its duties as a dust collector and a dry scrubbing reactor.

Higher smelter production rates cause increases in the quantity of hydrogen fluoride in the gas, higher gas temperatures which in turn reduces the HF/alumina reaction rate, and greater gas volume. This then requires an increase in the amount alumina particulate to react with the increased hydrogen fluoride and to compensate for the lower reaction rate. The GTC is therefore subject to increases in both gas volume and particulate dust load, resulting in higher operational pressure drop and more frequent pulse cleaning. Increased pulse cleaning yields higher particulate emissions with each pulse spike, and greater hydrogen fluoride emissions in the more frequent disruption to the reactive filter cake. This effect of greater smelter production on emissions and filter media life is illustrated in Figure 1.

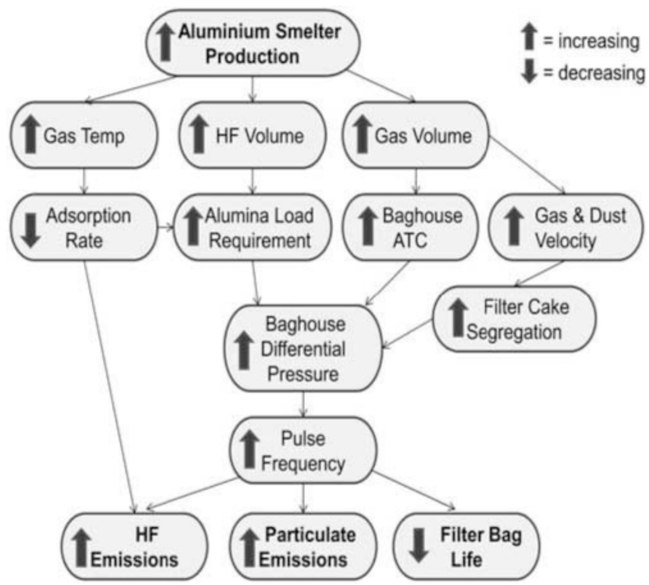

Figure 1: increased smelter production

Introduction To Extended Surface Filter Technology

Extended surface filter technology was originally developed to provide an alternative to capital equipment upgrades in dust collectors whose design was insufficient to meet increasing capacity requirements. The Ad-Flow^{TM} extended surface filter bag (figure 2) is designed to offer approximately 80-90% increase in available filtration area compared to a traditional cylindrical filter bags, and is constructed with a traditional filter media that has been proven in the application.

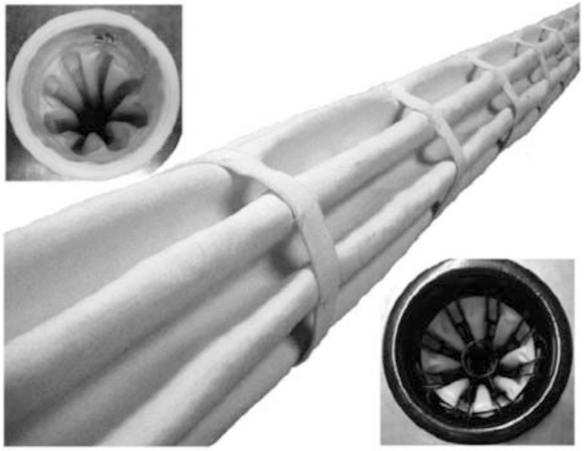

Figure 2: Ad-Flow™ extended surface filter bag

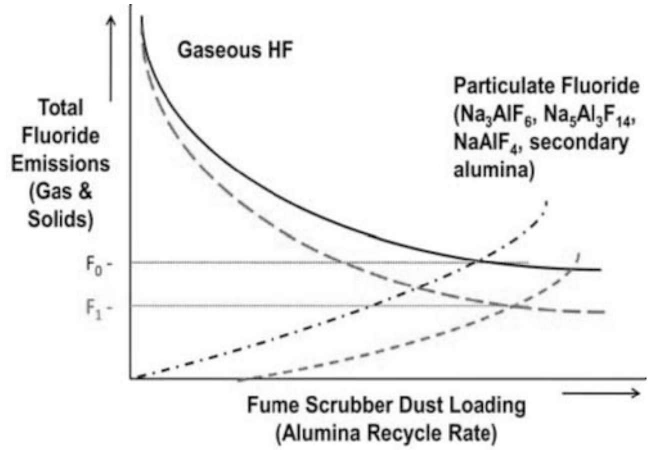

Figure 3: optimal operation of standard filter bags

C.R.N. Silva et al. [3] in their work on gas velocity in fabric filters theorised that filter cake porosity decreases and cake specific resistance increases with an increasing superficial face velocity. Conversely it holds that filter cake porosity increases and cake specific resistance decreases with decreasing superficial face velocity. C.R.N. Silva et al used the Ergun correlation with experimental data to demonstrate the direct relationship between superficial face velocity, filtration area and cake porosity.

This understanding helps explain that aside from additional filter surface area available, the extended surface filter bag and cage combination offers other benefits. A broader distribution of dust cake over a greater filtration area provides dramatically reduced gas and dust velocity at the face of the filter, yielding lower particulate emissions from a significant reduction in pulse frequency. The lower face velocity also alters the morphology of the filter cake, resulting in less resistance to air flow and greatly improved dust cake release.

Theory Of Extended Surface Filters In Potline Fume Scrubbing

Fluoride emissions from aluminium pots and fume scrubbers exist in both gaseous form as hydrogen fluoride and solid form as compounds of aluminium and sodium fluoride. Gaseous fluoride emissions are controlled by the effective scrubbing of the gas stream with solid alumina, and solid fluoride compound particulate emissions are controlled by effective operation of the dust collectors.

The Light Metals Research Centre [4] on page 96 of their Fluoride Emissions Guide illustrated that gaseous HF emissions increase with increasing pulse cleaning frequency. In the same publication on page 86 they illustrate that particulate fluoride emissions increase with increasing dust load, while gaseous HF emissions increase with decreasing dust load. In the GTC these parameters meet at an optimal operation point (see point F_o in Figure 3) as increasing gas and dust load in the dust collector leads to more frequent pulse cleaning and higher fluoride emissions, both particulate and gaseous.

The introduction of extended surface filters into potline fume scrubber dust collectors dramatically reduces the face velocity of the dust on the filter surface, and an ability to accommodate a significantly increased dust loading. The combination of higher dust load capability, lower gaseous fluoride emissions, and lower fluoride in particulate emissions results in a new optimal operation point (see point F_1 in Figure 3).

Therefore the expected benefits of extended surface filter technology in aluminium potline fume scrubbing include: lower gaseous fluoride emissions, lower particulate fluoride emissions, reduced pulse cleaning frequency, longer filter bag life (see Figure 4), and therefore a lower production cost per tonne of aluminium. Once again the Light Metals Research Centre [4] Fluoride Emissions Guide suggests on page 80 that extended surface filters are a cost effective way of lowering fluoride emissions and baghouse differential pressure by increasing the available filter media surface area.

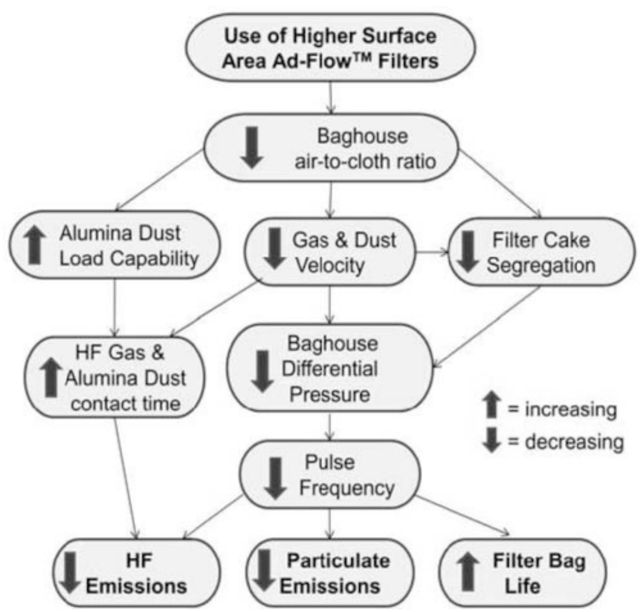

Figure 4: effect of extended surface filters

Application of Extended Surface Filters

Background To The Smelter Gas Treatment Centre (GTC)

Two major aluminium smelters, one in Australia and one in Canada, have undertaken wholesale conversions of full potline GTCs with over 20,000 filters in each smelter to take advantage of extended surface technology. Both these installations have existing GTCs which were designed to use standard type cylindrical fabric filter bags.

The results published [5] for the Australian Smelter conversion to extended surface filters in 2008 have now been replicated with further applications in other Smelters. Since converting to Ad-Flow™ extended surface filters, both smelters in Australia and Canada have achieved similar results showing significant efficiency and productivity gains when compared to the results from the standard cylindrical filter bags and these results have been summarised below:

- 35% reduction in filter differential pressure
- 20% less load on the fans saving $250,000 per year
- 50% reduction in pulse frequency
- 45% reduction in particulate emissions from the GTC's
- 45% reduction in gaseous HF emissions from the GTC's
- Debottlenecked the GTC. Allowed increased rate of alumina recycle during the hotter months of the year maintaining GTC HF emissions below license limits all year round.
- Further savings in aluminium fluoride consumption in the pots

Background into increasing GTC operating temperature

As production rates in aluminium smelters increase, so too does the GTC operational temperature. Previous studies and applications have shown that the proper application of the extended surface technology is able to cost effectively address the increased gas and dust load imposed on smelter GTC's. However with further increasing duration of seasonal high temperature operation, the operational temperature limitations of traditional polyester filter media are resulting in ever diminishing filter media life through thermal degradation of the polymer.

Traditional polyester filter media is rated by the fibre manufacturers to withstand continuous dry heat operation up to approximately 132°C. With trends towards capacity creep, many aluminium smelters around the world are now experiencing lengthy seasonal high temperature GTC operation.

One such smelter in Australia has a GTC operational temperature over the summer period with continuous dry operation at 145°C and even up to 150°C in some areas of the GTC. Laboratory tests have shown that operation at such high temperatures for just one month over summer can cause thermal degradation to the polymer normally seen over 12 months of operation at the more traditional 130°C. The life of the traditional polyester filter media in such aluminium smelter GTC applications has therefore been reduced with thermal degradation of the polymer, and in some cases filter life has been half that previously enabled at lower temperature operation.

Alternative Polyester Polymers

Introduction to Industrial Filtration Polymers

With the still relative low cost of traditional polyester fibres, a consequential move towards a commercially available higher temperature fibre for hot gas filtration would typically result in a significant jump in price of the filter. Such a change towards traditional higher temperature polymers, while enabling a significant step change in temperature resistance, could be considered over engineering for the 10°C to 20°C increase in temperature resistance required for standard polyester filter media to withstand typical seasonal changing GTC gas conditions.

Figure 5 illustrates the comparative recommended maximum dry operational temperature of traditional synthetic fibres used in industrial filtration, as well as a comparative price indication of these fibres in relation to standard polyester. The next commercially available higher temperature industrial filtration polymer is shown on the chart as polyphenylene sulphide (PPS), which is approximately 7 times the cost of traditional PET polyester.

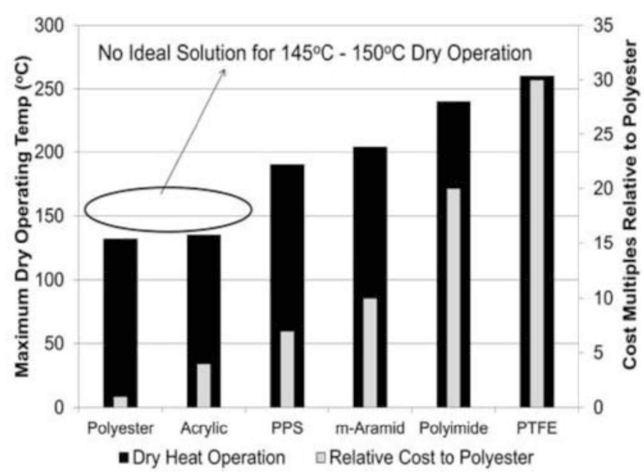

Figure 5: traditional industrial filtration polymers

Introduction to Filter Failure Mechanisms

In order to improve an industrial filtration media design, it is necessary to understand the shortfall in the design of the standard media and therefore understand the premature failure mechanism. Thermal degradation of the polymer, as described in the introduction to aluminium reduction potline fume treatment above, typically results in a shortening of the polymer chain, and in some cases invokes some cross linking between these shortened polymer chains. This increases the crystallinity of the polymer and this can be identified in the laboratory by a decrease in tensile strength and a decrease in elongation at break.

Typically in pulse jet fabric filter applications, such thermal degradation of the polymer leads to a reduction in media flexibility, and ultimately flex fatigue failure where the media flexes around the supporting cages wires as the media oscillates between modes of filtration and reverse pulse cleaning.

Polyester

Polyester is defined as any one of numerous synthetic polymers produced chiefly by reaction of dibasic acids with dihydric alcohols. The most common of these polyesters is polyethylene terephthalate (PET). There are a wide variety of other higher grade polyesters and some of the semi aromatic polyesters include polycyclohexanedimethylene terephthalate (PCT), glycol modified polycyclohexanedimethylene terephthalate (PCT-G), polybutylene naphthalate (PBN), polytrimethylene terephthalate (PTT), and polybutylene terephthalate (PBT).

It should be noted that these grades of polyester vary greatly in their physical properties, typical applications, and cost. It is also possible to create copolymers with more than one of these polyester polymers to target a specific outcome. One such example is where the Shakespeare Company [6] created a copolymer of PET and PCT to achieve greater hydrolytic stability in a monofilament yarn for application in the dryer sections of paper making machines.

Furthermore there are many possible of grades of polyester within each polymer type. Typically the degree of polymerization, as designated by the tested intrinsic viscosity (IV), can dictate the appropriate end use of the polymer. For example, there are many applications for the different grades of standard PET polyester as shown in table 1. Typically industrial filtration media is manufactured from fibre grade PET, although filtration media is available in higher cost polyester grades such as PBT and PBN.

Table 1: PET polymer comparisons

RPET Applications	Intrinsic Viscosity [g/dl]
Wool Type Fibre	0.58 – 0.63
Cotton Type fibre	0.60 – 0.64
Films	0.60 – 0.70
Textile Filament Yarn	0.65 – 0.72
Technical Yarn	0.72 – 0.9
Tire Cord	0.85 – 0.98
Injection Moulded Bottles	0.9 – 1.0

New Aluminium Smelter GTC filter media

Advancetex International has undertaken a series of both physical and commercial design trials and thermal aging tests of the physical design trials. The aim of these trials was to establish a cost effective new filter media which could better withstand the summer temperature peaks which are becoming more common in aluminium smelter GTC's than the typically used standard PET media, while retaining the same or better chemical resistance.

From this study a new range of filter media has been developed, the Advancetex PLUS™ range of media, and the media developed specifically for aluminum smelter GTC is the new Advancetex PLUS™-TR higher temperature polyester filter media. This new media is a proprietary blend of a variety of different grades of high grade polyester. The structure of the design has been constructed to address both minimising the economic impact of high grade polyester components and targeting an increase in thermal resistance to better cover the seasonal periods of high temperature operation in aluminum smelter GTC's. The design has also been constructed in a manner which enables this media to be used in either standard GTC fabric filter bags, or extended surface GTC fabric filter bags.

Laboratory Scale Thermal Aging Test Procedures

Samples of the typical standard polyester filter media and the new higher temperature polyester filter media were prepared for tensile tests as per ASTM D5035-06 and placed free of tension in a laboratory oven for thermal aging comparison tests. To accelerate thermal aging, separate tests were run at 160°C and at 180°C. In each test samples of both the standard PET and the higher temperature polyester filter media were removed on a regular basis and tested for retained tensile strength.

Laboratory Scale Thermal Aging Test Results

At the time of writing this paper, thermal aging studies had been conducted over a two week period at 160°C and a one week period at 180°C. The trends at different thermal decay temperatures were repeatable over different time scales, and the results of the crosswise filter media tensile strength results are included in figures 6 and 7 for the aging tests at 160°C and 180°C respectively.

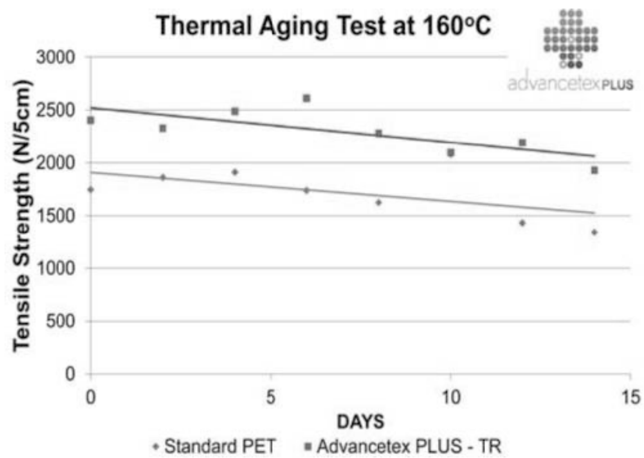

Figure 6: Tensile Strength Thermal Aging Test at 160°C

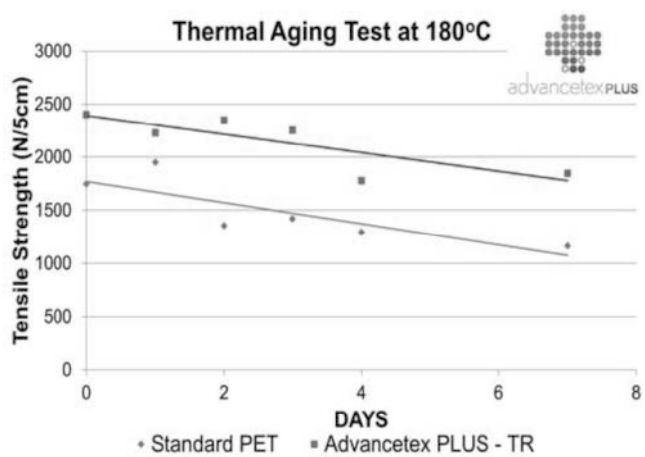

Figure 7: Tensile Strength Thermal Aging Test at 180°C

Both media demonstrated a similar rate of thermal degradation at these elevated temperatures. However the higher temperature polyester filter media started with a significantly higher tensile strength than the standard PET filter media. At the conclusion of all the tests, the remaining strength in the higher temperature polyester filter media was close to that of the standard PET filter media at the start of the thermal aging tests.

Furthermore, it was evident in both tests, that the rate of decay of elongation at break was much greater in the standard PET than the higher temperature polyester filter media (figures 8 and 9). This indicates a slower change in polymer crystallinity in the higher temperature polyester filter media for the same thermal exposure.

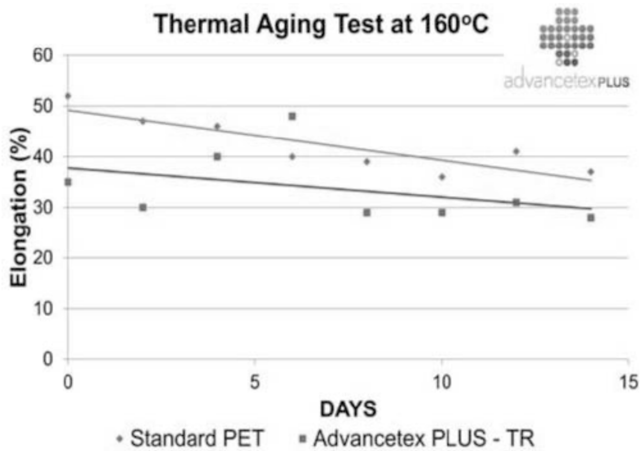

Figure 8: Elongation Thermal Aging Test at 160°C

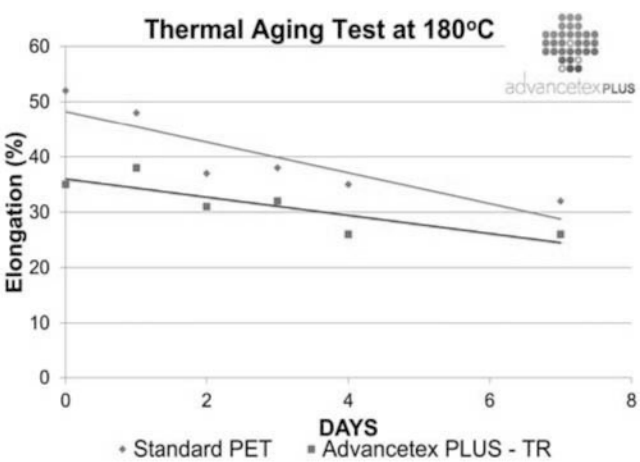

Figure 9: Elongation Thermal Aging Test at 180°C

Conclusion

This paper has discussed the theory of aluminium potline fume scrubbing and the potential benefits of utilising extended surface filters in the gas treatment centres to increase capacity. This theory has been verified and quantified with the wholesale conversion of smelter GTCs in Australia and Canada which have utilised extended surface filters to increase capacity and reduce aluminium production costs.

A new high grade polyester filter media Advancetex PLUS™-TR has been developed for the GTC's in aluminium smelters to address increasing operational gas temperature. This new media has been designed and constructed to operate adequately at periodic temperature excursions where the GTC operational temperature reaches 145°C to 150°C over the summer season.

The media design addresses the significant cost gap in progressing to other commercially available polymers for high temperature applications by minimising the cost increase of high grade polyester incorporation while maintaining the chemical resistance in the aluminum smelter GTC environment (see figure 10).

Preliminary laboratory studies have demonstrated that significantly greater initial tensile strength of the Advancetex PLUS™-TR polyester filter media decays in a similar rate to the standard PET polyester filter media. However the greater initial strength will enable this new filter media to endure higher temperatures for a longer period than the standard PET polyester filter media.

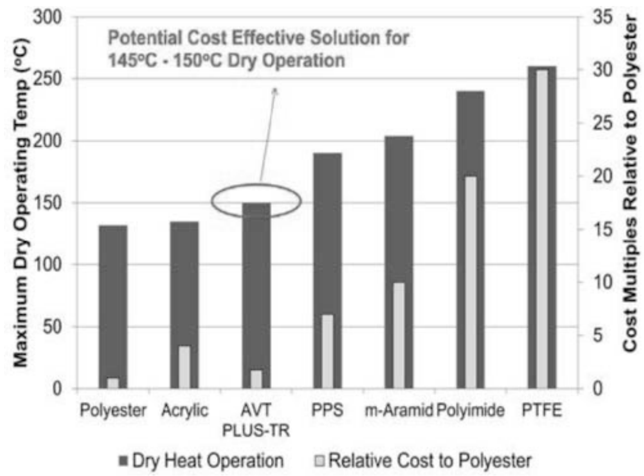

Figure 10: Potential solution for 145°C-150°C operation

Further Work

Further longer duration laboratory thermal aging studies are being conducted at a greater variety of exposure temperatures to further validate these findings. An aluminum smelter in Australia is currently conducting long term plant trials to verify the increase in longevity of the Advancetex PLUS™-TR polyester filter media over the standard PET polyester filter media in extended surface filter bags currently used in the smelter GTC baghouses. Economic analysis needs to be undertaken to ascertain whether the relatively small increase in cost enables an economically viable increase in filter media operational life in aluminum smelter GTC which operates at seasonally high temperatures.

Further work is also currently being conducted with new extended surface filter designs to accommodate non-cylindrical shaped filter bag conversion, as well as even greater capacity increase adaptations of the current cylindrical bag to extended surface filter technology conversions.

Such adaptations include the oval shaped extended surface filters (see figure 11) for increasing the capacity of existing low pressure clean baghouses which currently utilise oval shaped fabric filters rather than cylindrical shaped filters.

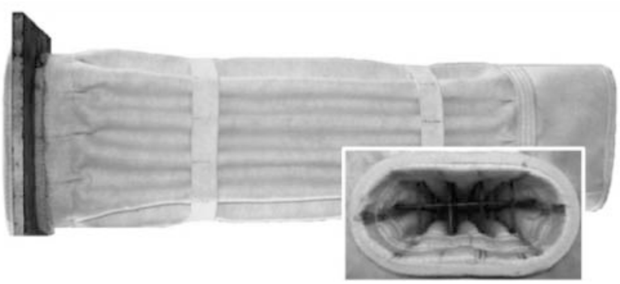

Figure 11: Oval Ad-Flow extended surface filter

A further adaptation to obtain increases in available filtration area of over 120% compared to a standard fabric filter bag is the Ad-Flow™ PLUS filter (see figure 12). This design uses a modified cage design to allow extra fabric pleats without compromising on the dust loading capacity of each pleat.

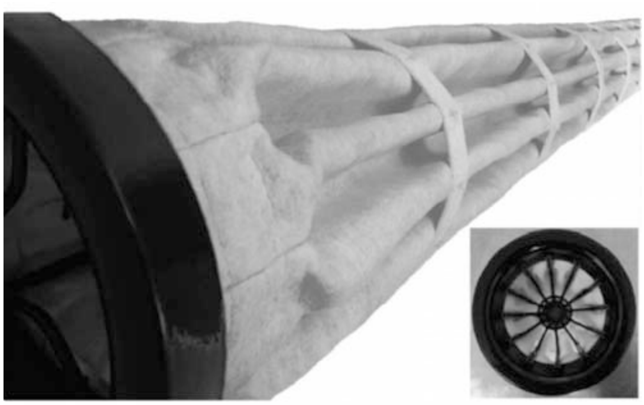

Figure 12: Ad-Flow PLUS extended surface filter

Both these extended surface filter adaptations are installed in trial filter compartments in aluminium smelter GTC's in Australia. Further work on these trial filtration cells will aim to quantify process advantages when compared to the standard fabric filters, as well as the current accepted extended surface filter technology.

Trial filtration cells will be monitored for differential pressure, pulse cleaning frequency, particulate emissions, and gaseous hydrogen fluoride emissions. The results of these trials will be published when complete.

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