Fabric Filter Operating Results with 10 m Long Bags and Low Purging Pressures

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Abstract

Environmental performance of the Gas Suspension Calciners for Alumina installed at QAL and Yarwun in Queensland, Australia, is secured by fabric filters.
Gas Suspension Calciners equipped with Fabric Filters represents today's State of the Art of stationary calciners for Alumina.

This paper describe the development of the fabric filter technology relevant for this application including selection of filtration medium from an environmental and cost efficiency point of view.

A three year R & D project has demonstrated that in all relevant aspects 10 m long bags can be used for general filter performance within the standard design rules of FLSmidth A/S, Airtech – Air Pollution Control. Purge pressures as low as 1.5 to 2 bar g has proven sufficient at "Standard Conditions".

FLSmidth has been offering filters with 10 m long bags to customers worldwide in Alumina and Cement market segment since quite some time.

Five fabric filters orders or ESP conversions have been received so far with 10 m long bags.

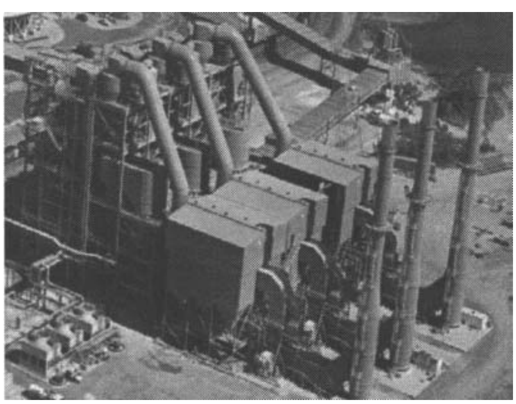

Figure 1a. 3 x 4500 tpd GSC units at QAL

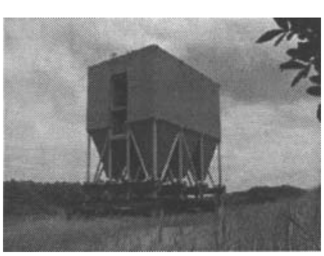

Figure 1b. Fabric Filter – Yarwun Refinery

1.0 Introduction

While Bag or Fabric Filters has been and still is extensively used to control the acid gas emissions (HF) from the smelters in the Aluminium industry since long back, it is only recently that stationary calciners has been equipped solely with fabric filters to control the dust emission.
The first application of fabric filters was at the 3 x 4500 tpd Gas Suspension Calciners (GSC) delivered by FLSmidth to QAL in 2002 and commissioned in 2004.The selection of Fabric Filters instead of Electrostatic Precipitators at the time was environmentally driven based on the Fabric Filter providing an absolute barrier to dust emission during situations of power failure in the Refinery. Shortly thereafter Fabric Filters was also selected for the 2 x 2300 tpd GSC units to be installed at the then new Yarwun Alumina Refinery (Figure 1b).
Since then, both Yarwun Alumina and Worsley Alumina has decided to expand their refineries and calcination capacity and again selected Fabric Filters to be installed on their new 2 x 3200 tpd and 3500 tpd GSC units, respectively.
This new trend in Air Pollution Control set by Australian Alumina refineries has now transpired to India, where AnRak Aluminium also selected Fabric Filters for their new 2 x 3000 tpd GSC Units.
All the above applications of Fabric Filters are with 6 m long bags. The last two Yarwun filters are equipped with 8 m bags.The required emission levels today are lower than previously increasing the utilization of fabric filters as being more cost effective than Electrostatic Precipitators. Furthermore, the ability of Fabric Filters to reduce odour due to their proven ability to be a reactor between an absorbent and a gas phase component has increased the focus on Fabric Filters even more.
This paper will focus on fabric filters with:

Long filter bags in combination with Low Pressure Cleaning offering the following advantages:

- Reduced emissions and odour
- Lower differential pressure across the filter
- Lower compressed air consumption rates
- Reduced electric energy consumption
- Prolonged filter bag life by low purging pressures
- Minimized capital and operational costs
- Reduced steel required for the filter construction
- Less civil work
- Decreased filter footprint
- Lower filter weight
- Facilitates faster and more efficient conversion of ESP's to hybrid filters or fabric filters. The 10 m long bags are utilizing the height of the converted ESP casing better than shorter bags

Fabric filters with 10m-long filter bags are becoming an increasingly popular choice for cement and minerals plant owners. FLSmidth installed its first 6m-long filter bag in a FabriClean™ Pulse-Jet fabric filter at Norcem in Brevik, Norway in 1998. As

plant emission regulations and plant operation and maintenance budgets became tighter and tighter, the demand for larger and more effective filter bags grew. To meet these demands, FLSmidth increased the size of its filter bags from 6 to 7 metres, then from 8 to 9 metres, and now 10m-long filter bags are available. Suitable for turnkey projects, as well as electrostatic precipitator (ESP) to hybrid or fabric filter conversions, FLSmidth currently has over 320 long bag filter houses in operation in cement and minerals plants around the world. And, by the end of 2011, FLSmidth's 10m-long filter bag technology will guarantee that emissions and operational costs are kept low in India for the largest single casing and filter area kiln filter in the world.
With a long life span and stable performance, 8m-long filter bags have been the preferred filter bag size for both fabric and hybrid filters for cement and minerals plants for many years. At the Titan Kamari plant in Greece for example, a hybrid filter with 8m-long bags has operated at an A/C=1.4 m/min, with a differential pressure as low as 8.5 mbar.

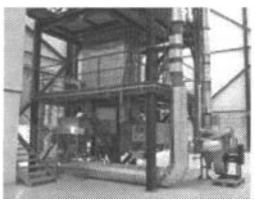

Figure 2. Pilot filter 10 m bag test rig

Figure 3. Star shaped cage

Figure 4. Bottom of cage

2.0 Putting the 10m-long filter bags to the test

The FLSmidth's R&D team wanted to design a 10m-long filter bag that would be able to operate at low differential pressures across the entire bag house, while still cleaning the filter bags efficiently from top to bottom, with minimum flex fatigue to the filter media due to the "low pressure cleaning" concept. In 2009, testing began on the 10m-long filter bags at the company's R&D Centre Dania at Mariager, Denmark. To certify this design achievement, they carried out four main tests with: filter load or air to cloth ratio, A/C (m/min), purge pressure (bar g), valve opening time (ms) and dust flow rates (g/Am3) as variables. Common success parameter and benchmark was the specific air consumption required for maintaining stable filter operation at each of the selected parameters.
The tests showed that the 10m-long bags were suitable for all industrial fabric filter applications. At purge pressures as low as 1.0 bar g for 3" valves, 2 bar g for 2.5" valves and 3 bar g for 2" valves/blow tubes, the bags worked effectively under the relevant standard conditions. These are defined as: A/C=1.2 m/min with on-line cleaning, 30 g/Am3 dust load, purge pressures of 1.5 to 2.0 bar g, 100 ms electric valve opening time, 10 or 15 mbar differential pressure across the tube sheet and test temperature at 130 deg. C.

3.0 The 'genuine' low pressure cleaning concept

The low pressure cleaning concept at 2.0 bar g and below is appealing because compressed air generated at this low pressure can save between 40 and 70 percent in electric power consumption compared to systems with higher purge pressures. The power saving is partly due to the 'blower concept', which is possible at pressures up to 2 bar g, rather than the traditional compressors necessary to operate at higher pressures. The "low pressure cleaning" concept is therefore defined by FLSmidth for cleaning pressures up to 2 bar g. This definition applies regardless of whether the filter operates with on- or off-line cleaning. The difference of cleaning mode becomes however of less importance at purge pressures below 2 bar g. It follows that the low pressure cleaning option is only possible with 3" valve and purge tube systems due to higher cleaning air flows.

Figure 2 shows the 10m-long bag pilot fabric filter test rig with the integrated single bag test filter. Figure 3 shows the characteristic star shaped cage for holding the filter bag with the venturi on top which collects the purge air and generates high amount of secondary air flow enhancing the bag cleaning. Furthermore it prevents the excessive wear of bags. Figure 4 shows the special bottom part of the cage which protects the bag bottom and simultaneously increases the internal pressure in the bag during the cleaning pulse. The result is enhanced cleaning and/or energy saving by less requirement of compressed air. Alternatively lower pressure requirement.

4.0 Impressive results

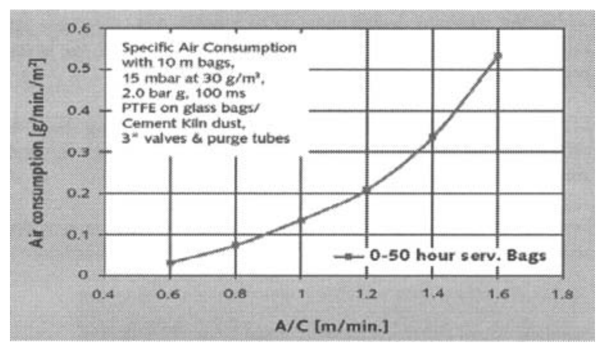

Figure 5. Specific air consumption at variable A/C values

The graph in figure 5 shows that the filter performance is stable across the whole investigated A/C range. However, as compressed air consumption increases as a result of increasing A/C levels, it may be advantageous either to increase the purge pressure and/or the valve opening time.

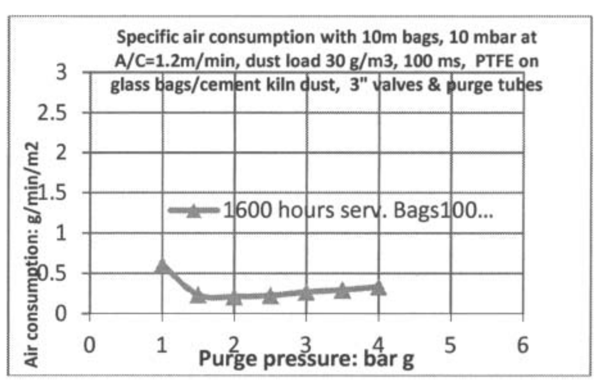

Fig. 6. Specific air consumption at variable purge pressures at 10 mbar filter differential pressure and bags with 1600 hours service. Focus is on "Low Pressure Cleaning".

These results confirm that it is possible to operate at purge pressures equal to or above approximately 1.0 bar g for 3" valves at on-line conditions. Higher pressures are required if smaller valve sizes are used. In fact, the specific air consumption is relatively constant from the minimum cleaning pressure to the higher purge pressures at around 4 bar g. This is because the FLSmidth Filter SmartPulse Controller, SPC 800 automatically regulates the number of purges required at any purge pressure. It reduces the number of cleaning purges at higher purge pressures, which results in relatively constant specific air consumption.

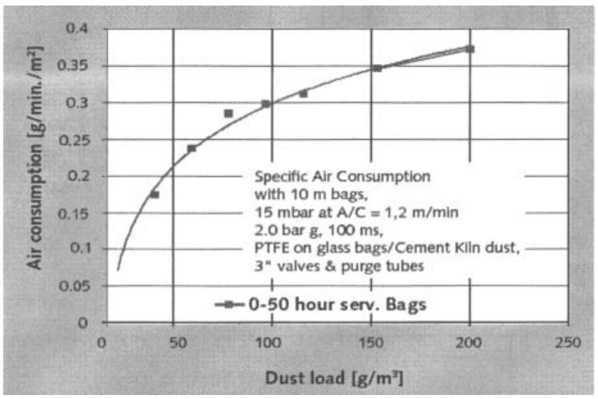

Figure 7. Specific air consumption at variable dust concentrations

The specific air consumption flattens out at higher dust load concentrations because not all of the dust attach to or even reaches the surface of the bags with increasing dust load. It is observed that the 10m-long bags can be effectively cleaned within the whole dust load range. The same applies for the filter with 10m-long bags equipped with 2 or 2.5" valves at somewhat higher purging pressures. Purge pressures required also depends on how many bags are provided with cleaning air from the same purge tube/valve.

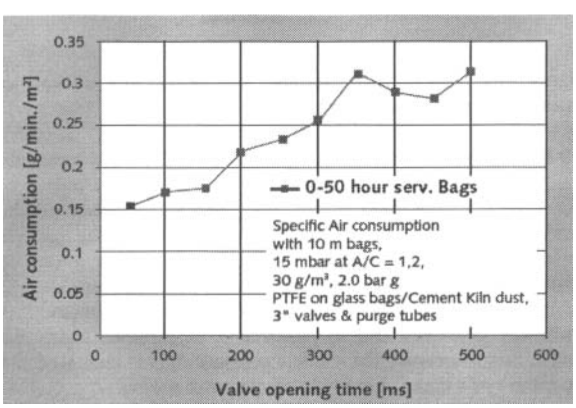

Figure 8. Specific air consumption at variable valve opening times

Fig. 8 shows that effective cleaning can actually be obtained at electric opening times as low as 30ms. It is seen that operating at higher opening times may be a waste of compressed air. The specific air consumption increases proportionally as a function of opening times. Nevertheless tests in this paper generally are based on 100 ms. Tests also demonstrated that the actual mechanical valve opening time is approximately equal to the electric opening time, plus approximately 50ms.

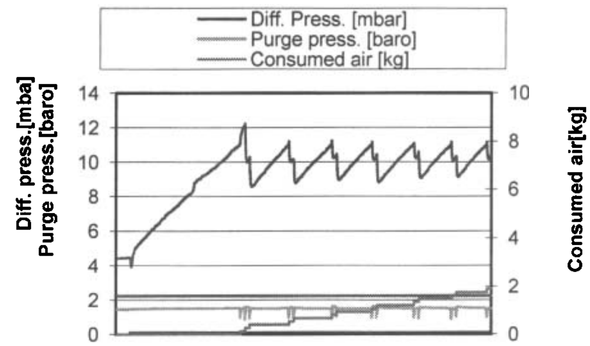

Figure 9. Stable filter operation at the selected operating parameters- low pressure cleaning- and standard operating conditions: 10 mbar differential pressure, purging with 1.5 bar g at 100ms and dust load 30 g/m3 with 10m-long bags of PTFE on glass, 3" valves & purge tubes.

5.0 Emission and permeability test of new bag media types

Virgin filter (bag-media) emission test has also been performed on the one bag filter rig with a newly purchased instrument Durag D-RC-80 MD "Gravimetric Measuring Device" which is well suited to measure the ultra small particle mass captured during operation. The instrument sampled the emitted dust over two periods of four hours each, which was found to be suitable.

Material	Emission (mg/Nm3)	Permeability in l/m2	
		150 Pa	200 Pa
A1	0.200	1500	1800
B1	0.053	2200	Not measured
C1	0.286	2100	Not measured
C1	0.224	1800	2100
PTFE/glass	0.730	1500	1800
PTFE/glass	0.590	1500	1800

Table 1. Emission and permeability test results of virgin fabric filter bags 6 m long with Ø 127 mm diameter.

The emission test of each bag was performed at the following conditions:

- Temperature in the filter: 130 deg. C.
- A/C= 2.7 m/min was kept constant for all bags. The relatively high A/C value had to be chosen in order to have stable pressure drop in the one bag filter.
- Dust load was kept constant.
- Differential pressure across the tube sheet varied between 2.3 and 6.2 mbar according to the differences measured in permeability of the bags.
- Purge pressure: 3.5 bar g.
- **Constantly purging at 20 s time interval over entire time interval**
- Test dust: "Foderkalk" (Rollovit)

According to the data sheet of the PTFE on glass media manufacturer the permeability should be within the range of 1,92 – 3,84 ($m^3/min/m^2$ at 200 Pa or 20 mm wc) for comparison.
It seems interesting that the two versions of the newly developed bag materials B1 and C1 by far exceeds the permeability of the traditional PTFE on glass media and the A1 which is another "traditional" filter media type.
The B1 emission is outstanding low compared with the other values. Moreover the B1 material is also having the highest permeability. Perhaps the B1 represents a new filter media candidate for the future FLSmidth filters.

The above test results constitute a preliminary indication of a remarkable new filter material.

Performance, ageing and clogging tests over prolonged time of service will show further evidence in the future.

6.0 Measurement of particle emissions during pulse jet cleaning before and after the ageing of the filter media

Black peaks indicate number of particles: (P/cm3)
Green peaks (greyish) indicate emission by mass: (mg/m3)

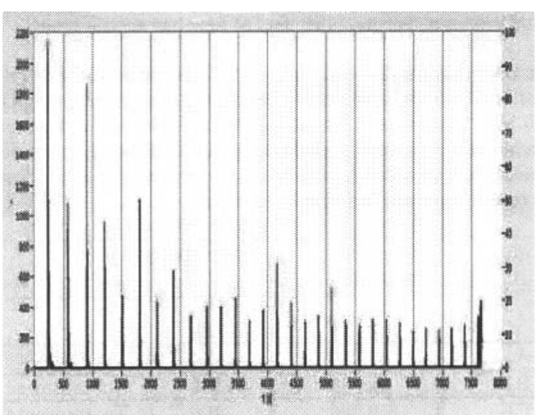

Figure 10a. Particle emissions measured by mass and by number vs. time during the initial 30 cycles according to VDI 3926. (Reference 1).

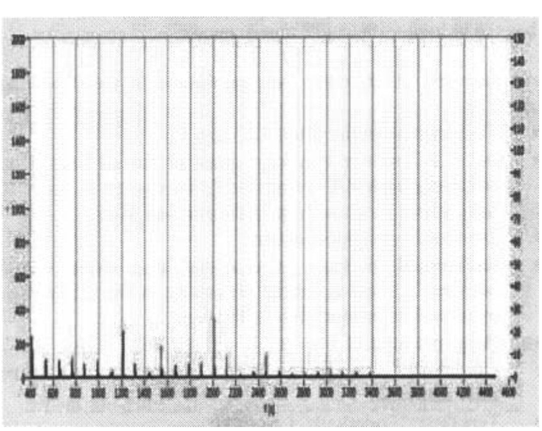

Figure 10b. Particle emissions measured by mass and by number vs. time after ageing with 10.000 cycles according to VDI 3926. (Reference 1).

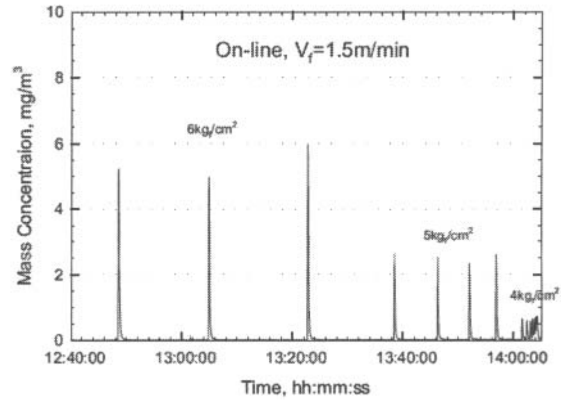

Figure. 11a. Dust emission through bag filters with on-line jet pulse cleaning (Reference 2).

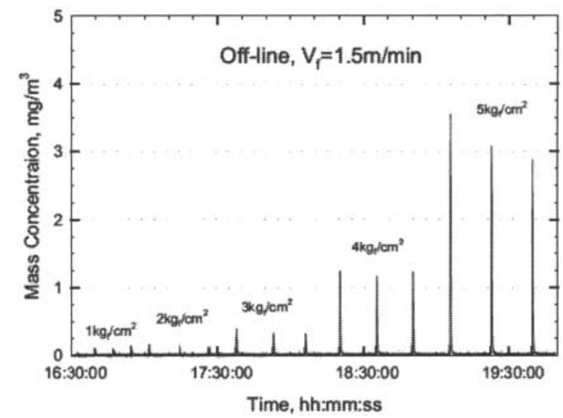

Figure 11b. Dust emission through bag filters with off-line jet pulse cleaning (Reference 2).

7.0 Summary of emission and operating(OpEx) considerations

The ageing of the filter media has a strong influence on the residual pressure drop, the mean cycle time and the particle emissions in the downstream. In the first 30 cycles it can be observed that the particle emission continuously decreases.
After the ageing of the filter media the particle emission is drastically decreased due to penetration of particles inside the media. Simultaneously the residual pressure drop is increased and the mean cycle time is becoming shorter after ageing.

It is critical to operate bag filters at optimum settings which obviously call for as low purge pressures as possible. Pressure vs. volume ratio of the purge air is free to be adjusted within certain limits. Higher pressures mean smaller dimensions of the entire purge system with higher emissions and more wear of the bags, whereas low purge pressures, means larger dimensions, lower emissions and longer bag life.

The cost of electric power to operate the ID fan to overcome the differential pressure of the filter may be the highest single item followed closely by the cost of the fabric filter bags. The third most, however less important element in the operating costs are the electric power cost to generate the compressed air for effective cleaning of the bags and thereby keep the ID fan operating costs low. The interaction between these three cost elements are therefore important to optimize the operating costs (OpEx) and an example is given on these considerations in Table 2 below. As can be seen from this table it would be obvious to reduce the differential pressure from 15 to 10 mbar by application of more compressed air.

From figure 11a and 11b it is evident that emission wise it does not make much of a difference whether the filter operates on- or off-line in case the purging pressure is kept below 2 bar g.

From Table 1 it is observed that a 2mg/Nm^3 emission requirement is within reach and FLSmidth confirms the ability to guarantee emissions below this level.

Fig. 11b demonstrates that ageing of the filter media reduces the emissions. This is furthermore confirmed by tests made by filter media suppliers on bags with 29 moths service life. Sometimes however, PTFE membranes on glass bags nevertheless produce higher emissions as a function of increasing number of service hours. This is often explained due to erosion by the dust of the fragile membrane or other filter malfunctions, such as bags scraping on the steel structure of the filter interior, causing cracks or bare spots in the ultrathin PTFE surface membrane. These higher emissions are normally avoided by careful filter design such as CFD analysis of flow in the filter compartments in order to assure a perfect flow and dust distribution.
The filter casing construction and the fixture of the bags in the tube sheet are other potent emission sources which have to be controlled during the filter design and construction phase.
At the same time it is also clear that the above results and examples are representing only one case at a time. I.e. one dust, one filter, one bag media one set of process parameters and so on. Therefore each new proposal case have to be investigated thoroughly and based on a set of reliable process conditions and other relevant information before guarantees can be made on emissions below 2 mg/Nm^3.

8.0 The FabriClean filter for up to 10m-long bags

The today FabriClean filter is a result of FLSmidth's substantial experience within the electrostatic filtration technology as well as more than 320 fabric filters built over the past years plus the above mentioned extensive R&D tests in long bag technology applying low pressure cleaning. The major features of the FabriClean filter are:

- Low pressure cleaning equal to or below 2 bar g
- Side entry with gas/dust distribution
- Down flow in bag zone split into compartments
- Used in power boilers, mineral industry, waste incineration etc.
- On- or Off-line cleaning/maintenance possible at customers request

Figure12.FabriClean filter installation at Worsley

The gas and dust distribution system applied for the FabriClean filter is an area of the highest priority.
In ESP conversions it is a must to perform an individual CFD analysis to ensure optimum performance.
In the FabriClean filter dust loaded gas enters the inlet duct from the process and flows through the inlet dampers into the individual compartments. The gas expands as it enters the distribution chamber and baffles and deflector plates ensure that most of the dust is deposited directly down into the hoppers as it is precipitated due to the reduced velocity by gravity. This reduces the dust burden on the filter bags resulting in a significant decrease in the cleaning frequency whereby the pulse air required to clean the filter bags is reduced and hence the wear on the bags.
As the size of pulse jet filters increases, good gas and dust distribution becomes essential. On smaller filters the inherently high-pressure drop is sufficient to distribute the gas and dust reasonably even throughout a compartment. As compartments become larger it is important that consideration is given to control the distribution and not just leaving it to chance. When a filter is cleaned online, the direction of the gas flow in the compartment is important. The FabriClean filter has gas flow that is predominantly down across the bags. This minimises the problem of re-entrainment that can give rise to unstable and excessive pressure drops in poorly designed filters.

9.0 Control system and instrumentation of the FabriClean

In most processes with bag filters it is extremely important to keep the filter in operation at all times. In this context of availability the instrumentation and control system play a key role in order to alarm any malfunction that may occur so adequate intervention can be made.
On-line maintenance can be achieved when the compartments are equipped with isolation dampers at inlet and outlet to the compartments and separate dust hoppers with an isolation device. Also, instrumentation to monitor the correct function of the cleaning process and automatic valves to isolate the supply of compressed air in case of failure is standard.
FLSmidth has developed a modern control system; SmartPulse Controller (SPC) tailored to control fabric filters. The control system includes a large number of routines that help operating the filter at a minimum cost and ensure malfunctions are identified and can be attended to quickly and dealt with effectively.

Examples of typical malfunctions are a broken bag in a given compartment, a purge valve failing to open or close etc.
The control system is designed for either serial or parallel interface to the plant control system. Each compartment is equipped with node boxes for control of valves and dampers.

A differential pressure instrument monitor the resistance to flow across the filter and will, when required, initiate a cleaning cycle.

Consecutive cleaning of the bag rows will continue until the pressure drop across the filter has reached a predetermined level. The controller will then stop the cleaning sequence. When the pressure drop rises again above a predetermined level the controller will re-activate the cleaning cycle from where it stopped. This effect can be seen in figure 9.

The compressed air manifolds for each compartment will be fitted with a pressure transmitter to monitor the correct performance of the purge valves. When the valves are activated the pressure in the compressed air manifolds is detected to monitor that the valve opens and closes correctly.

Each compartment outlet duct is fitted with a simple dust monitor. The function of this instrument is to provide an alarm in case bags fails and starts to pass dust to the clean side.

10.0 Focus on the 10 m bag advantages

- Lower capital outlay, lower operation and maintenance costs
- Fewer bags & cages and fewer dampers
- Smaller filter footprint and lower weight
- Less steel and less civil work
- And "Low pressure cleaning" is still possible < 2 bar

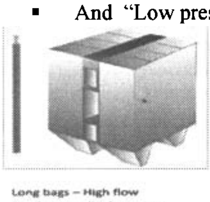

Figure 13. Long bags

Figure 14. Short bags

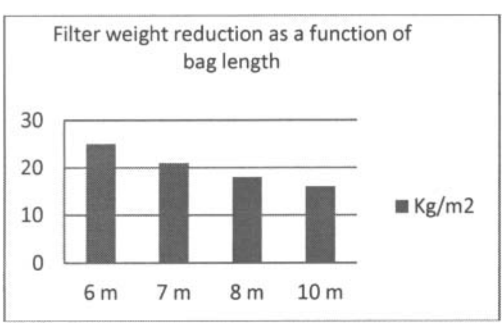

Figure 15. Filter weight reduction

Four references on 10 m long bags:

- JK Cements, Mangrol, India, 8000 x 10m-long bags, New FabriClean™ filter for preheater kiln
- Baticim Line 1, Turkey, 2640 x 10m-long bags, RetroClean for preheater kiln
- Baticim Line 2, Turkey, 2640 x 10m-long bags, RetroClean for preheater kiln
- Batisöke, Turkey, 1485 x 10m-long bags, RetroClean for preheater kiln

References for fabric filters with 7-8 m long bags amount to 100 whereas the number is 219 for 6m and below.

11.0 Conclusions and/or Recommendations

The today's state of the art FabriClean filter has been presented from a technological point of view including some facts on OpEx for a specific project which has been estimated and compared with an ESP as well as an ESP/FF-hybrid for the same duty in Table 2 below. The selection of a FabriClean is a sound choice also from this point of view.
The hybrid solution however, as it comes to an ESP conversion, gives the overall lowest OpEx as well as CapEx.
This paper has hopefully explained why the FabriClean filter is a "BATNEECOE". (Best Available Technology Not Entailing Excessive Cost or Emission).

OpEx Comparison for Filter Options with emissions <10 mg/Nm3. 0.1 EUR/kWh				
Comparison of operating costs		**ESP**	**ESP/FF-hybrid**	**FF**
Flow	m3/s	308	308	308
ESP	#fields	4	2	0
Gas velocity	m/s	1,26	1,39	
ESP dP	mmWG	20	10	0
ESP power	W/m2	28	20	0
A/C	m/min	0	1,24	0,97
Bag length	m	0	10	10
Bags	#		3.172	4.774
FF dP	mmWG	0	60	150
Bag life	yrs	0	6	5
Operating time	hrs/yr	8.000	8.000	8.000
Bag cleanning	#/yr		8.000	16.000
Compress air	kWh/yr	-	29.240	53.088
ID-fan efficiency	-	0,82	0,82	0,82
El. power	EUR/kWh	0,1	0,1	0,1
OPEX - ESP	EUR - el (TR)	492.912	159.840	-
	EUR - el (heat)	16.000	8.000	-
	EUR - dP	58.937	29.468	-
OPEX - FF	EUR - air		2.924	5.309
	EUR - dP		176.810	442.024
	EUR - bags/yr		54.981	66.836
Total	**EUR/yr**	**567.849**	**432.023**	**514.169**
			-24%	
			19%	
Compressed Air Calculation :				
0.118 kW / Nm3/h = 0.09145 kWh/kg at 8.5 bar incl. Drying&cooling				
12.6 g / pulse in each bag on hybrid (Av. 23/15 bags/valve 2.5", 3 bar g, 100ms, 220 l tank)				
7.6 g / pulse in each bag on FF (17 bags/valve 2.5", 3 bar g, 100 ms, 120 l tank)				

Table 2. OpEx comparison between ESP, FF and a hybrid solution

12.0 References

1). Dipl.-Ing. (FH) Martin Schmidt, Palas® GmbH, Greschbachstr. 3b, 76229 Karlsruhe, Germany, paper presented at Filtech 2011 Conference, "INFLUENCE OF THE DUST ON THE FILTER EFFICIENCY AND EMISSIONS OF CLEANABLE FILTER MEDIA".
2). Hyun-Seol Park and Kyoung Soo Lim, Korea Institute of Energy Research, Daejeon, Korea, paper presented at Filtech 2009 Conference, "DUST EMISSION CHARACTERISTICS OF PULSE JET BAG FILTER