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OPTIMIZATION OF PULSE JET FABRIC FILTER IN POWER GENERATION

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Abstract-

As we know the fabric filter are frequently used for the separation of fine dust particle from gas stream. The aim of this study is to use of various types of fibres polymers and yarn types to increase the life of bag and studying them at various temperature. The paper also discuss recent trend in power generation by using pulse jet fabric filter. In India more than 60% of power is developed by using thermal power plant and the emission from such power plant is dangerous from environmental point of view. So by using different types of polymer and yarn types here we study effectiveness of Pulse jet Fabric Filter.

***Key Words*- Polymers, Pulse jet Fabric Filter**

(I) Introduction.

As an Engineering Practice, fabric filter, or bag house, collects the dry particulate matter as the coaled flue gas passes through the filter material. The development of fabrics for fabric filter bags has been limited because of the restricted availability of suitable polymers. The fabric filter comprised of a multiple compartment enclosure (see Fig.1) with each compartment containing several meters longs vertically supported, small diameter fabric bags. The gases pass through the porous bag material which separates the particulate from the flue gas. There are several types of fabric used for filter bags in India according to its chemical and physical properties they are used at various temperatures and several other conditions which satisfied the particular requirement of that bag house or fabric filter. Here we discussed the few polymers which are mostly used in fabric Filters. Substantial research and development on bags and their materials have taken place to lengthen their life and to select bags for various applications. The flexing action during cleaning is the major factor affecting bag life. Bag blinding which occur when small particulate becomes trapped in the fabric interstices, limits bag life by causing excessive pressure drop in the flue gas. Finishes on the bag surface are also used to make enhance cleaning. The most common bag material in coal-fired utility units reverse fabric filters is woven fibreglass.

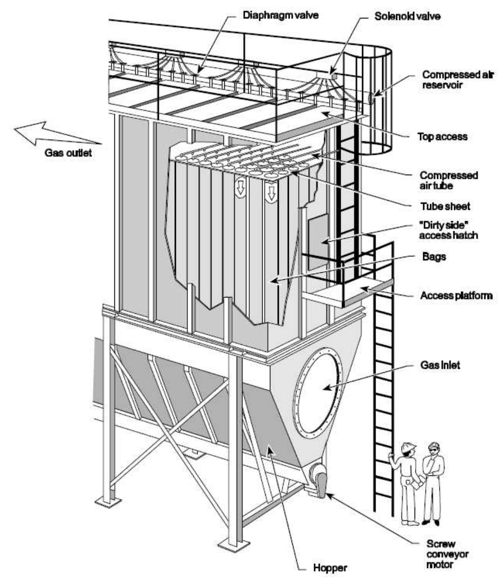

Figure: 1 Typical pulse jet fabric filter

Typical bag size is 12 inches.(305mm) diameter with a length of 30to 36 ft (9.1 to 11.0 m). Bag life of three to five years is common. The shake deflates filters also use mostly fibreglass bags. On both of these units, the fibreglass bag is fastened at the bottom to a thimble in the tube sheet .At the top, a metal cap is fitted into the bag and the bag has a spring loaded support for the reverse air filters. The bags are attached to the tube sheet commonly using a thimble and clamp lees designed bag. The upper operating temperature limit is 500F (260C) for most fibreglass bags. The most common bag material in coal-fired utility units with pulse jet fabric filter is polyphenylene sulphide (PPS) needled felt. In addition to polyphenylene sulphide, fibreglass, acrylic, polyester, polypropylene, Nomex, P84, special high temperature fibreglass media, membrane covered media, and ceramic are used in various applications. For the pulse jet filters, the typical bag size is 5 or 6 in (127 or 152 mm) diameter round or oval with a length of 10 to 26 ft (3 to 8 m).Advance in cleaning technology are increasing the ability to provide longer bags. Pulse jet bags are commonly sealed to the tube sheet using a snap-band seal. The bag is supported internally from a metal wire cage to prevent bag collapse during operation. Cages are normally carbon steel and may include a variety of coating from pre-galvanized to coated wire. Some applications use a stainless steel cage.

(II) Filter bags are used using following fibres-

- POLYSTER
- POLYPROPYLNE
- ACRYLONITRILE
- RYTON
- NOMEX
- PTFE
- GLASS FIBRE

A) Polymers

The following fibre polymers are in common use:
Fibreglass,
Homopolymer Acrylic (PAN)
Polyphenylene Sulphur (PPS)
Also used are:-
Polyimide (P84)
Polytetrafluoroethylene (PTFE)

B) Nomex

Nomex Filter Bag manufacture by nomex needle punched felt filter cloth which have high working temperature (204-240), anti-acid, anti-alkali, high filtration blow speed, low pressure drop, anti-break, and anti-abrasion.

Nomex Filter Bag easily be hydrolyzed in the condition of high temperature, which mostly applied in pitch mix gas, blast furnace gas in steel factory in steel factory, gas, tail gas of white char, kiln applications, electric cooker high temperature gas, etc.

Compositions		Nomex /Nomex Scrim		
Weight (g/m2)		450	500	550
Thickness (mm)		1.8	2.0	2.2
Air permeability (m3/m2·min)		21	17	14
Tensile strength(N/5 20cm)	Warp	>800	>800	>800
	Weft	>1100	>120 0	>130 0
Tensile Elongation(%)	Warp	<35	<35	<35
	Weft	<55	<55	<55
Broken strength (Mpa/min)		2.55	2.40	2.35
Working Temperature(°C)		≤ 204	≤ 204	≤ 204
Short time Working temperature(°C)		240	240	240

C) Ryton

Ryton Filter Bag manufacture by COX Filter Cloth.

Ryton Filter Bag can bear chemistry nurturing inherently, keep good filtration performance among the abominable environment and reach ideal service life.

Ryton Filter Bag working temperature is 190 degree and instant working temperature can reach 220 degree, which is the best filter media for anti-acid, anti-alkali, hydrolysis resistant, but pps filter bag not so good at anti -oxidant, and applied in waste treatment, electric station boiler, industrial boiler, etc.

Ryton Filter Bags widely for dust collecting in cement plant, iron and steel plant, power plan, chemical plant. PPS Filter Bag also used in coal boiler, rubbish incinerator, power plant of fly ash filtering of pulse clear dust catcher PPS filter fabrics are an ideal filtration material.

Material		PPS Bag(needle felt fabric)
Basic Weight (g/m2)		500
Thickness (mm)		1.8
Air permeability (m 3 /m 2 /min)		>15
Tensile Strength	Warp	>1250
	Weft	>1350
Elongation (%)	Warp	≤40
	Weft	≤60
Burst Strength (Mpa/min)		2.55
Continues Working Temperature		190 (□)
Instant Working Temperature		220 (□)
Finishing Treatmen		Signed,calendering, heat-set

D) Glass fibre

Fibreglass filter bag widely used in world industries to remove particulate from process & ventilation air and to recover valuable resources from any manufacturing process. COX fibreglass filter bags, dust collector filter bag add a dimension of versatility & diversity with a multitude of designs, thus allowing you select the best model to solve your dust control needs.

Fibreglass filter bag is an excellent new type of high temperature resistance filtration material, which uses 100% fibreglass as raw material. The fibreglass filter bags' filtration speed is higher than other filtration material and suitable for use in the filters.

Fibreglass filter bags and C fibreglass filter bags is the basic kinds bags to manufacture. Thickness from 0.6~0.9mm. The max weight of bags can reach 900g/m$^{2.}$

E) Homopolymer Acrylic (PAN)

The mechanical properties of this fibre allow it to be used for varied fabric constructions. It has relatively good textile fibre properties which allow it to be spun economically into yarns for the production of woven fabrics. Its mechanical properties also allow it to be used for the production of needled fabrics. The chemical resistance properties of the fibre make it ideal for the use in the collection of fly ash particularly for Australian and South African coals with lower sulphur content. There are several drawbacks however, with PAN fibre which has meant that the usage of the fibre has slowly decreased over recent years. PAN's maximum long term operating temperature is 135°C. This means that for the efficient low term life of the bag, attemperation, usually by the induction of ambient air, is required to maintain the gas stream below this temperature. This increase in air volume means that a larger fabric filter with increased cloth area is required for efficient filtration performance. The lower gas temperature can also mean that there is an increased possibly of the fabric experiencing acid dew point excursions. This can degrade the fabric and is an important point to consider especially as higher sulphur content coals are being used. The fibre has an inherent shrinkage problem that becomes evident over longer operating life. This fibre shrinkage can not be eliminated completely by heat setting treatment of the fabric. During the development of fabric filters in the early 1970's this fibre was easily accessible, comparatively inexpensive, with the results that several large power stations in India were built using fabric filter bags manufactured using PAN fibre.

F) Polyphenylene Sulfar (PPS)

The use of this fibre became popular in the 1980's as it became commercially available. The fibre has an advantage over PAN fibre because of its increased thermal resistance. The Fibre can operate at a constant 190°C. This means that the majority of fabric filters can operate without flue gas stream air attemperation. The fabric filter therefore can be smaller in Size compared to one using PAN fibre. This is an important factor when retrofitting a fabric Filter into an Electrostatic Precipitator casing. At higher operating temperatures there is less chance of fabric operating near or below the acid dew point. The fibre is also less susceptible to shrinkage than PAN, with any fabric shrinkage being mostly eliminated by effective heat setting. The fibre is much more expensive that PAN fibre, but can be cost effective over the life of the boiler because of longer filter bag life expectancy and less fabric surface area required for a given boiler output. The fibre can be affected by high levels of NOx in the gas stream. Like wise the presence of bromides in the gas stream can have an adverse affect on the life of the filter bags. Almost all new and retrofit fabric filters today are using PPS fibre. There is also a trend for fabric filters originally fitted with fabric produced using PAN fibre being converted to fabrics using PPS fibre.

Table 3 Typical Glass Fabric Specification

Fibre	Fibre Glass
Weave	3 x 1 Twill
Warp yarns	Multifilament
Weft Yarns	Multifilament-air texturized
Fabric Weight	470 g/m²
Operating temperature	260°C
Fabric Finish	Silicon/Graphite/Teflon

G) Polyimide (P84)

This fibre has a maximum operating temperature of 260°C.The fibre has not found wide spread use in flue gas filtration in utility power stations for several reasons:

i) The fibre is very expensive.

ii) The fibre is susceptible to acid hydrolysis. P84 fibre is used in a small number of industrial boilers where the high boiler outlet temperatures limit the use of other fibres. The fibre has also found a limited use in some power stations where the capture of fine ash particles is required to meet emission standards. The P84 fibre has a trifocal shape which has proven to give improved small dust particle retention due to the fibres increased surface area. The P84 fibre is used as a fine layer on the filtration side of a standard PPS or PAN fabric.

H) Polytetrafluoroethylene (PTFE)

The maximum operating temperature of this fabric is 260°C. The fibre has excellent chemical resistance to most chemicals. However very few fabric filters in the power generation industry have been fitted with this fabric for the following reasons:

i) The fabric is extremely expensive. The cost of the fabric means that it is used only in conditions that are highly caustic or acidic and operating at high temperatures.

ii) The fibre is very smooth and a poor textile fibre. This means that the fabric is hard and expensive to produce. It also means that the fabric is very hard to stabilise in fabric finishing. There can be problems with stretching and/or shrinking during filtration operation.
This characteristic is due to the low fibre to fibre surface friction, which also assists its dust release capabilities.

iii) The fibre/fabric is a poor filtration fabric. The fibres are very smooth meaning that ash particles are not easily collected. Higher emission levels are expected with this fabric. The low surface friction due to the "non stick" characteristic of the PTFE, allow the dust particles to continue to "work through" the filter media.

(III) Fabric Construction

Woven fabric and Needled fabric are both used in fabric filters. The type of fabric construction has closely followed the requirements of mechanism of the fabric filter being used. Typically fabric filters use the following fabric constructions:
Reverse air Fabric filters Woven fabrics
Shake fabric Filters
Woven Fabrics (Figure 1)
Reverse Pulse Jet Filters
Needled Fabrics (Figure 2)

Figure 2 Woven Fabric

Table 1 Woven Fabric

Development of Woven Fabric

- Fibre glass <260° C
- Homopolymer Acrylic (PAN) <130° C
- Surface Foam Coated PAN <130° C
- Polyphenylene Sulphur (PPS) <190° C
- Blended PPS and PAN <135° C
- Chemical Treatments

Figure 3 Needled Fabrics

Table 2 Needled Felted Fabrics

Development of Needled Fabrics

- Homopolymer Acrylic (PAN) <130° C
- Polyphenylene Sulfar (PPS) <190° C
- PPS With surface Treatments <190° C
- PPS with PTFE encapsulation <190° C
- PPS with Blended or capped webs (P84) <190° C
- PTFE (PTFE) <260° C

(IV) Reverse Air Fabric Filters

This type of fabric filter with a low air to cloth ratio (ATC) gives low mechanical stress to the fabric used in the filters. The use of glass fabric is almost universal in these types of filter in power generation applications. {3}

Fibreglass fabric filters has played a large part in the collection of fly ash in the utility boilers in The United States of America. These fabric filters have been developed over a large number of years to increase the life of bags using such devices as sonic horns for cleaning. The result is that operation life of the filter bags has been extended to over 10 service years.

The low air to cloth ratio of these fabric filters means that they are large with large cloth area used to ensure efficient filter operation. Very few fabric filters of this type have been installed in recent years in any power station. There are no utility boilers in Australia using this technology.

(V) Shake Fabric Filters

For any type of cleaning enough energy must be imparted to the fabric to overcome the adhesion forces holding dust to the bag. In shaker fabric filter cleaning is done with inside or outside gas flow, energy transfer is accomplished by suspending the bag from a motor-driven hook or framework that oscillates. Motion may be imparted to the bag in several ways, but the general effect is to create a sine wave along the fabric. As the fabric moves outward from the bag centreline during portions of the wave action, accumulated dust on the surface moves with fabric. When the fabric reaches the limit of its extension, the patches of dust have enough inertia to tear away from the fabric and descend to the hopper.

The fabric chosen for the start up operations was woven Homopolymer PAN using identical fabric specification at all three stations. Since start up, the operation of the station and the variation in fuel parameters from station to station has entailed the changing of the fabric specification to suit the different flue gas conditions. There is a range of fabric specifications which include blends of fibre in the yarns and foam coated fabric. Table 4 gives one variation of fabric used. Figure 4 depicts a foam coated surface used at two of the stations. The variation in power station parameters also means that there is a range of filter bag operating life from station to station. This life ranges from 30,000 to 65,000 service hours. This extended life was evident in well maintained fabric filters.

Table 4 - Typical Fabric for Shake Filters(Woven)

Fibre	PAN
Size	2.2 Dtex
Weave Pattern	2 x 2 Twill
Fabric Weight	375 g/m²
Fabric Thickness	1.2 mm
Air Permeability	9 m³/m²/minute @ 125 Pa Pressure
Fabric Finish	Heat set / singed/ Foam coated

(VI) Reverse Pulse Jet Fabric Filters

Reverse air cleaning was developed as a less intensive way to impart energy to the bags is stopped in the compartment being cleaned and reverse (outside in) air flow is directed through the bags. This reversal of gas flow gently collapses the bags toward their centrelines, which causes the cake to detach from the fabric surface. The detachment is caused by shear forces developed between the dust and fabric as the latter changes its shape. Metal caps to support the bag tops are in an integral part of the bag as several sewn-in rings that encircle the bags to prevent their complete collapses during cleaning. Without these rings, falling collected dust tends to choke the bag as the fabric collapses in on itself while cleaning. As with Multi-compartment shaker baghouses, a similar cycle takes place in reverse-air baghouses of stopping forward gas flow and allowing dust to settle before cleaning action begins . the source of reverse air is generally a separate system fan capable of supplying clean dry air for one or two compartments at a gas-to-cloth ratio as high or higher than that of the forward gas flow . Fig. illustrate a reverse air pulse jet fabric filter {8}

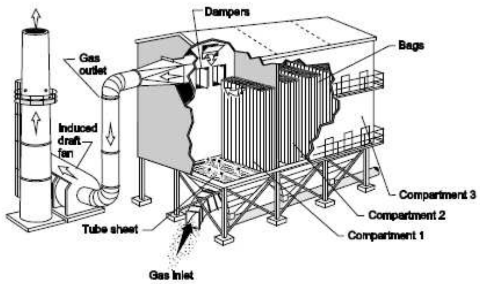

Figure 4: Reverse pulse jet fabric filter

In Thermal power station applications used fabric using Homopolymer Acrylic (PAN) fibre. As PPS fibre became available commercially and its performance was accepted, more fabric filters were installed using this fibre. The increased temperature resistance of the fibre has the affect of eliminating the requirement for air attemperation. This permits lower cloth area compared to a fabric filter using PAN fabric. This is particularly important when converting an Electrostatic Precipitator shell to a fabric filter and space is at a premium. There has also been a trend of converting earlier fabric filters from PAN fibre to PPS fibre. Almost all of fabric filters installed on pulse jet filters in Utility boilers are using PPS fibres, whether they are new installations or retrofitted applications. The typical fabric specification for a needled fabric is outlined in Table 5. The fabric is comprises a woven scrim, fibre web, mechanically entangled. The web equally distributed on each side of the scrim. There will usually be some type of fabric surface finish utilised. (Fig. 5)

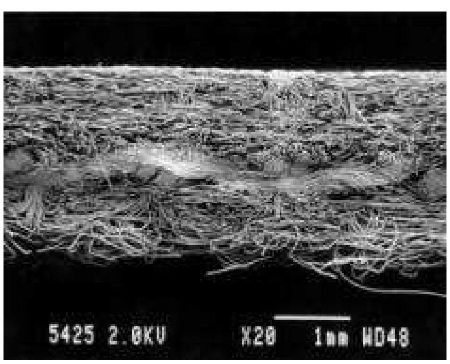

Figure 5 Needled fabric

Table 5 Typical Needled Fabric Specification

Fibre Type	PPS
Fibre Size	2.2 Dtex
Fabric Weight	600 g/m^2
Fabric Thickness	2 - 2.5 mm
Fabric Scrim (Base)	Woven PPS
Air Permeability	10 m^3/m^2/minute @ 125 Pa Pressure
Fabric Finish	Heat set/ surface treatment

(VII) Future Developments

In conventional pulse-jet baghouses, bags are mounted on wire cages to prevent collapse while the dusty gas flows from outside the bag to the inside during filtration. Instead of attaching both ends of the bag to the baghouse structure, the bag and cage assembly generally is attached only at the top. The bottom end of the assembly tends to move in the turbulent gas flow during filtration and may rub other bags, which accelerates wear. Often, pulse-jet baghouses are not impartment. Bags are cleaned one row at a time when a timer initiates the burst of cleaning air through a quick-opening valve. A pipe across each row of bags carries the compressed air. The pipe has a nozzle above each bag so that cleaning air exits directly into the bag. Some systems direct the air through a short venturi that is intended to entrain additional cleaning air. The pulse opposes and interrupts forward gas flow for only a few tenths of a second. However, the quick resumption of forward flow redeposits most of the dust back on the clean bag or on adjacent bags. This action has the disadvantage of inhibiting dust from dropping into the hopper, but the advantage of quickly reforming the dust cake that provides efficient particle collection.

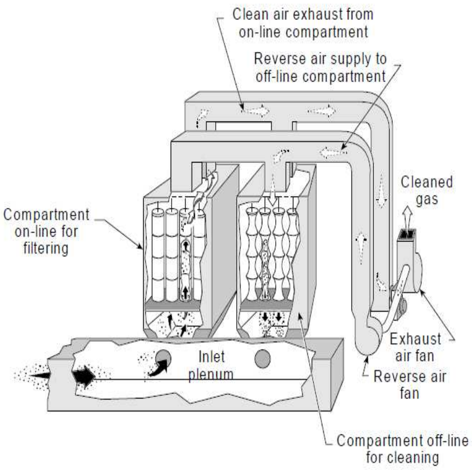

Figure 4Typical Reverse-Air Baghouse
(Courtesy of North Carolina State University)

To increase filter area in the same volume of baghouse, star-shaped and pleated (in cross section) bag/cage configurations have been developed. The bag/cage combination is designed as a unit to be installed similarly to a standard bag and cage unit. Such units can be used as replacements for standard bags and cages when additional fabric area is needed or may be used in original designs. Normal pulse cleaning is used, i.e., no special changes to the cleaning equipment are required. Costs for star-shaped bags and cages are about three to three and-a-half times normal bags and cages. Aside from additional filter surface area available, the cage combination offers other benefits. Improved dust cake release characteristics have been observed due to the increased flex motion of the filter media during pulse cleaning. A broader distribution of dust cake over a greater filtration area provides dramatically reduced air and dust velocity at the face of the filter, yielding lower particulate emissions and a significant reduction inpulsefrequency. The substantial decrease in the inner volume of the bag can allow up to 50% reduction in the quantity of compressed air required, at lower pressure, for media cleaning in some applications {9}

Figure 10 Cage Installation

(VIII) Test Results

Testing of filter bag along with recommended 15.5 oz/yd² PPS with ePTFE membrane filter media was performed in-house following testing protocol used in EPA's ETV program using the same type of equipment utilized by EPA/ETV and in accordance with ASTM Test Method D6830-02 along with the test specifications and conditions as detailed in Generic Verification Protocol for Baghouse Filtration Products (BFP). The protocol was adopted from German VDI Method 3926 and modified for the ETV. A 6-inch-diameter fabric filter sample is challenged with a standard dust (particulate matter) under simulated baghouse conditions at specified rates for air and dust flow. The test consists of three test runs. Each run consists of three sequential phases or test periods during which dust and gas flow rates are constantly maintained to test specification. The test phases are: A conditioning period of 10,000 rapid pulse filtration cycles (every 3 seconds) A recovery period to allow the test sample to recuperate from rapid pulsing where the filter is pulsed only when the differential pressure reaches 4" w.c. A 6-hour performance test period during which measurements for particulate emissions are determined by gravimetric measurement of the particulate matter that, passes through the sample. Particulate used for the test is 1.5 micron mass mean diameter with at least 50 percent less than 2.5 microns. {7}

Verification Test Results	16 oz PPS	15.5 oz PPS w/ ePTFE
Mean Outlet Particle Conc. $PM_{2.5}$ (gr/dscf)	0.0001834	0
Mean Outlet Particle Conc. Total mass (gr/dscf)	0.0001834	0
Initial Residual Pressure Drop (in. w.g.)	1	1.3
Change in Residual Pressure Drop (in w.g.)	0.07	0.02
Average Residual Pressure Drop (in w.g.)	1.04	1.32
Mass Gain of Filter Sample (grams)	2.18	0.11
Average Filtration Cycle Time (s)	136	222
Number of Pulses	53	32
Permeability		
Initial Perm $ft_3/min/ft_2$ (CFM) @ .5" H_2O	40.8	4.7
Perm After Testing	2.99	2.98
Percent Retained Perm	7.30%	63.40%
Removal Efficiency (%)		
Dust Conc. (gr/dscf)	8.23	8.23
$PM_{2.5}$*	99.997119	100
Total Mass **	99.997771	100

* (Dust Concentration * .7735) – PM2.5 Outlet Concentration * 100 Dust Concentration * .7735
** Dust Concentration – Total Mass Outlet Concentration * 100

Test Conditions Throughout the Test Were as Follows:
Test dust: Pural NF Alumina (1.5 ± 1 micron mass mean diameter)
Inlet dust feed rate: 8.0 ± 1.6 gr/dscf (18.4 ± 3.6 g/dscm)
Filtration velocity: 6.6 ± .5 fpm (120 ± 6 m/hr)
Gas temperature: 78 ± 4 F (25 ± 2 C)
Pulse cleaning pressure: 75psi
Testing was conducted to determine the filter sample's performance with respect to the following parameters:
Outlet particulate emissions (PM 2.5)
Outlet particulate emissions (total mass)
Initial residual pressure drop
Increase in residual pressure drop
Average residual pressure drop
Mass weight gain of the filter sample
Average filtration cycle time
Number of filtration cycles

The entire PJFF with the recommended 15.5 oz/yd², scrim supported 100 percent PPS with ePTFE membrane laminated to the filtration surface.

(IX) Conclusion

The success of stable , long term filtration of hot gases depends on both the conditions under which the dust to be deposit on the filter surface and on the cleaning action supplied, Based On comparison of parameter by using various polymer The use of fabric filters in power generation will continue to increase in the future. There is a continuous development Pulse Jet cleaning with various polymers. Fabrics have been developed to suit variable power generation operation, coal analysis and Filtration equipment design parameters. Filter life increased from 38 months to 62 months, lower operational costs were realized. The fabrics have been to meet emission limits, give extended life and be cost effective over the life time of the power station. New fibre, fabrics and technologies will continue to be developed to meet future emission Limits and operating requirements.

(X) References

[1] M. Crawford, Air Pollution Control Theory, McGraw-Hill, New York, 1976.
[2] D. Leith, R.W.Y. Allen, "Dust filtration by fabric filters, in: R.J. Wakeman ŽEd.., Progress in Filtration and Separation", vol. 4, Elsevier, 1986.
[3] P.W.Bowden, M.J.Neate,B.M.Currell and Erakios, "Fabric Filter For Power stations".
[4] M. De Ravin, W. Humphries, R. Postle, "iltration and Separation"Ž1988. 201–207.
(v) M. De Ravin,"Modeling the performance of fabric filters based on measurements of dust cake adhesion" PhD thesis, University of New South Wales, 1986.
(vi) J. Ju, M.S. Chiu, C. Tien," new pulse jet fabric filter, J. Air Waste Manage" Assoc. 50 Ž2000. 600–612)
(vii) GE energy April 2011 edition of POWER ENGINEERING by Penn Well Corporation.
(viii) Lesson 7 Industrial application of Fabric Filter {1 -21}
(ix) Cleanwell waste energy management {1-4}