INTRODUCTION:

In this article I would like to share the trends in the air pollution control (APC) equipments used over the past 15 years. I have also presented the future likely scenario for the Cement Industry in India.

Details are presented on the types of equipments and components used in the de-dusting of major process equipments such as, Raw mill, kiln, Cement Mill, Coal Mill and Clinker cooler.

The information will be useful to designers and consultants of air pollution control (APC) equipments of new cement plants. The information will be also useful to existing cement plants in upgrading their APC equipments for higher productivity, reduced power consumption and improved environmental compliance.

Process to be followed:

Let us review the trends in an organized fashion.

We will first look at general economic trends.

This will be followed by specific trends in the cement industry.

We will also briefly review the trends within the membrane filtration industry.

Then we will look at the trends and developments that have taken place in the fabric filter technology and how it has affected the selection of APC equipment for different processes.

Then we will look at the trends in Air Pollution Control technologies (APCT) applied to the cement industry in each of the process. We will also look at case histories in each of the processes.

1. GENERAL ECONOMIC TRENDS

Technology is transforming the way we do business. Communication system advances are bringing the world closer than ever before. Growth in developed nations has reached a plateau at 0 - 4 % or some countries are passing through recession. The growth in Asian countries by contrast is averaging 6-11 %. This phenomenal growth rate in Asia has caught the world’s attention in the last two decades. The ASIAN RIPPLE is changing the way world thinks about Asia.

The industrial explosion in Asia is bringing wealth for countries. It simultaneously brings some growing pains like major pollution problems. Knowledge from the west is also helping bring awareness into the Asian society. Some cement plants today have difficulty getting extensions for their operating permits. In addition to the air and water pollution concerns, the disappearing mountains and hills from the area (raw material quarries) are causing major ecological upheaval. Near big cities, polluting factories...
are closed down and shifted to remote locations. Because of the existing high levels of pollutants around a city, (Non-attainment area) the city government is clamping down on sources of controllable pollution (i.e. industrial exhausts).

2. GENERAL TRENDS WITHIN CEMENT INDUSTRY

Let us briefly talk about Cement Industry as it is today.

2.1. The cement industry has become very modern compared to before. Most companies have replaced their wet cement plants to dry. Most standard pre-heater kiln systems have been replaced by pre-heater pre-calciner kilns (most common kind are NSP type i.e. New Suspension Pre-heaters). Many others with one string of pre-heater cyclones are adding another string to improve efficiency further.

Similarly in cement grinding processes, pre-grinding roller presses have become a dominant trend. Most plants have replaced ball mill with roller mill for raw material grinding as well as coal grinding and drying. Coal mills and cement mill systems used to use fabric filter (FF) in auxiliary mode (cyclone as primary collector and fabric filter to collect the left over fines) are now switching to using FF as main process dust collector (FF used right after the mill and separator, without cyclones so dust load on FF has increased drastically).

Limestone Grinding—Limestone having Bond Index more than 14 kWh/t & moisture less than 2 % are economically processed by the ‘finish-grinding in RollPress’ mode. This would imply higher residual heat in kiln exit gases (as RP requires less conveying air). Barring a few cases Vertical Mills have become the standard for Raw Material Grinding.

2.2. Most new cement plants today are 2 MM to 3 MM ton capacity, hence economies of scale is applied. This economies of scale along with modernization of the equipment is reducing the cost of production. The pollution per ton of cement is also much lower today as a result.

2.3. Industry is also taking global shape. Some prominent worldwide players are emerging on all fronts of cement industry. Some of the global cement companies that have already entered India in the last few years are Holcim, Hidelberg and Lafarge.

3. PTFE MEMBRANE FILTRATION

Gore invented the microporous PTFE membrane technology in 1974. Gore’s India office was also the first company to introduce the technology in India in 1993. The author has published many articles in the past NCB seminars. The references are provided at the end of this article. For the benefit of those who are new to PTFE membrane technology, let me briefly go over the PTFE membrane technology.

3.1. Principles of filtration:

Expanded PTFE (ePTFE) membrane, provides the filtration. On one hand, it is microporous so doesn’t allow even the smoke particles to go through (particle size of smoke 0.01 ~ 1.0 μm). On the other hand, it is non-stick and moisture resistant, so particles don’t form heavy cake on the surface and slide off easily during a cleaning cycle. This provides steady state conditions and predictable ΔP on the FF.

Our pioneering experience with surface filtration principles as applied to industrial filtration for over 30 years in over 200,000 applications (20% of which are in Minerals industry) gives us an unique ability to face even toughest application with a lot of confidence. The confidence is easily transformed
into customer success with the help of worldwide resources. We believe we are a GLOBAL company to help our customer achieve a unique and optimum solution to their filtration challenges.

3.2. Trends in the membrane filtration industry.

The surface filtration concept with membrane filters became an important concept in the cement industry, as the industry started to look for more reliable filter media, lower emission standards and lower energy consumption.

Simultaneously, many new FF designs came into existence. Low pressure high volume pulse jet cleaning FF also became popular.

It is interesting to note that growth of GORE™ membrane filtration products (filter and cartridge elements) kind of parallels the industry modernization. As the new application or new ways to improve process came into existence, there was a new application where GORE® membrane provided better benefits and improved the process further. Of course most of these initial applications were localized to the USA., but in the last fifteen years, many surface filtration FF have been applied in India also.

The higher volumes and competition is also driving the cost of membrane filters downwards making them more and more suitable for wider range of applications. Gore is now also supplying filter media with the brand name of Pristyne Filter Media to a selected and authorized filter bag manufacturer in India, which offers the users in India one more source to get the high quality filter media.

3.3. What Is Gore’s Optimization approach?

It is our unique system of services which ensures the customer the success from our product. It involves a range of services which we mostly provide free of charge as a part of purchase. This way we take care of making sure that the problem is once and for all solved for the end user. We have been in India for over fifteen years and have established a comprehensive data base of various applications in Cement Industry. With the help of this approach, we have been able to collect a complete history of the application data base for many of our applications. We have also learned the typical maintenance practices followed in cement industry in India so that we can proactively support the cement industry to enhance benefits of membrane filter bags. It also allows us to use the application experience to improve our product further to suit additional applications.

For an example, we had some problems with one of our Kiln exhaust Fabric filter applications and cleaning system utilized in that FF was too severe for Fiberglass laminate. We have been able to modify our laminate and been able to supply the new set. This new set completed more than 60 months. This is just to illustrate the point that we support our products completely. We stand for our products and our customers.

3.4. Improvements achieved in GORE™ membrane technology:

The original Gore patent expired in 1992 and some USA based companies also introduced the PTFE membrane based technology. Over the last 35 years, Gore has improved the product by many folds and many articles have been presented in the past NCB seminars describing some of these developments.

The major focus of Gore’s research is aimed at reducing the filter drag without sacrificing the filtration efficiency. Thus, the 3 parameters which are the focus areas for Gore’s improvement efforts are:
a) **Filtration efficiency for 2.5 microns** and below dust particles. The particles below 2.5 microns are most harmful and represent the finest dust size present in cement processes.

b) **Residual increase in the pressure drop.** This is the measure of filter drag offered by the filter media during use after many cleaning cycles. It was found that depending on the quality of the membrane, the pressure drop offered by the “membrane” changes over time. This is measured by the increase in residual pressure drop.

c) **No. of Cleaning cycles.** This represents the cleanability of membrane. Some PTFE membranes can clean better than others. This means the no. of cleaning cycles required to achieve a certain pressure drop is different for different membranes. The life of the membrane and thus the filter bag depends on how frequently the media needs cleaning (pulsing). Lower the frequency better will be the bag life.

### 3.5. EPA’s ETV Test and summary of results for membrane medias:

Environmental protection Agency (EPA) is a US government agency in charge of pollution control in USA (equivalent of Central Pollution Control Board in India). EPA’s Environmental Technology Verification (ETV) Program develops testing protocols and verifies the performance of innovative technologies that have the potential to improve protection of human health and the environment and is designed to meet the following goals:

- Provide objective, credible performance data to purchasers
- Facilitate technology acceptance and permitting at the state/local level
- Level the playing field among competitors through standardized tests and objective reporting.

Any company with a commercial filter media can participate in this programme, with the condition that EPA will publish the test results on EPA’s website for the benefit of the users. The test results are formally reported in a verification document and posted on the ETV program website for public access. Additional information on the EPA ETV program can be found at the EPA web site. http://www.epa.gov/etv/vt-apc.html#bfp

Gore has prepared the following comparison summary after downloading the data from the website for four similar laminates. The four laminates compared below are having similar fiberglass backing fabric. Hence, the four laminates can be compared. The difference in the performance can be attributed to the difference in the quality of the membranes.

### 4. COMMENTS AND CONCLUSIONS

- Gore’s L3650 laminate offers much lower residual pressure drop. This means Gore bags will offer higher airflow through the bag filter/process or less number of Gore bags will provide the same airflow as filter bags manufactured from other membrane laminates.

- Gore's L3650 laminate was able to maintain lower pressure drop at much lower cleaning frequency compared to other laminates. This means Gore filter bags will wear less and provide longer bag life and lower pressure drop over the entire life of the bags.
Comparison of EPA’s ETV verification Data for Fiberglass Laminates

<table>
<thead>
<tr>
<th>Company Name / ETV Verification Date</th>
<th>Brand Name</th>
<th>PM 2.5 Emissions (g/dscm)</th>
<th>Average Residual Pressure Drop (cm w.g.)</th>
<th>Number of cleaning cycles (or pulses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W. L. Gore &amp; Associates, Inc.</td>
<td>GORE® L3650 Verification July 2006</td>
<td>Non detectable</td>
<td>2.45</td>
<td>87</td>
</tr>
<tr>
<td>Donaldson</td>
<td>Tetratex® 6255 Verification Sept. 2007</td>
<td>10 times higher than Gore</td>
<td>41% higher than Gore</td>
<td>82% higher than Gore</td>
</tr>
<tr>
<td>Donaldson</td>
<td>Tetratex® 6255-3 Verification Dec. 2008</td>
<td>Non detectable</td>
<td>46% higher than Gore</td>
<td>100% higher than Gore</td>
</tr>
<tr>
<td>GE</td>
<td>GE 061 Verification June 2009</td>
<td>Non detectable</td>
<td>23% higher than Gore</td>
<td>32% higher than Gore</td>
</tr>
</tbody>
</table>

5. TRENDS FOR AIR POLLUTION CONTROL TECHNOLOGY (APCT) WITHIN CEMENT PROCESSES

Let us look at these trends by different processes within a cement plant.

5.1. Kiln Exhaust Systems:

Kiln exhaust system is handling the highest airflow and hence is the most important de-dusting system in any cement plant.

Past:

The pollution control norm was 150 mg/Nm3 and most of the cement plants in India till 1990 had Electro-Static Precipitator (ESP) as their APCT for Kiln exhaust. Because of water shortage in some parts of India, conditioning tower was not feasible and hence the reverse air cleaned Fabric Filter (FF) was introduced, especially in parts of Gujarat and Rajasthan. In the rest of India the ESP was still dominant APCT. For better understanding for readers, authors have elected to use FF (Fabric Filter) to represent the terms “bag house” (normally used for reverse air cleaned system) and “bag filter” (normally used for a pulse-jet filters).

Over the next few years, fabric filters started becoming more common due to better pollution control than ESP. Cement plants improved their ability to operate and maintain the fabric filters. Bag life, emission and pressure drop, the three key performance parameters were all improved so much that when the emission norms were changed from 150 mg/Nm3 to 50 mg/Nm3 in 2005 by the central pollution control board, cement plants were almost ready to meet the new norms with fabric filter technology.

The recent trend is to replace these aging ESPs either partially or completely to FF (pulse jets and/or reverse air cleaned). Earlier the filter media applied were not as efficient causing major pressure drop and capacity related bottlenecks in the system. Also the bag replacement cost due to short life of the bags were a major cost which would tip the selection criteria away from choosing FF as an option. However, with the introduction of GORE® surface filtration media pressure drops as low as 50-120 mm WG could be achieved across the filter media despite the severe moisture and the fine particles.
in the stream. Also the bag life in excess of 4 years could be achieved. This shifts the selection criteria in favor of FF against ESPs. With the ability of GORE™ filter media to operate at high air-to-cloth ratio, thus reducing the size of the FF to a level where it is possible to fit the required no. of bags within the small existing ESP casing.

Main challenges and Future Trends:

- Wide variation in dust load & temperature given the mill-on & mill-off conditions.
- During the Mill-on condition, the scrubbing action of the mill reduces the dust load & temperature of the exit gas. Mill off case necessitates use of fresh air bleed-in to reduce temperature, leading simultaneously to higher moisture, higher volume of gas & presence of trace elements as chlorides from alternate raw materials / alternate fuels (not getting scrubbed-off). Special care has to be made to sizing criteria, use of materials to avoid acid attack, use of sacrificial conventional (?) bags & optimization of baghouse operation.
- Fuel flexibility deemed necessary by Cement plants
- Advent of Pulsejet bags with woven fiberglass laminated to PTFE membrane with low pressure pulsing has offered an alternative to RABH. The pulse jet technology has found wider acceptance in developed countries but in India, the life Cycle costing is increasing due to increase in the filter media cost. The pulse jet technology is relatively new in India and sufficient data is not available to say conclusively. Reduction in import duties, more experience and better filter design, increased bag life may lead to selection of pulse jet technology in future.
- MoEF stipulates CREBS norms & BAT to be adhered to. This implies moving towards 25mg/Nm$^3$ or even 10mg/Nm$^3$ in the foreseeable future. As plant equipments are expected to have a life of more than 25 yrs, it automatically stands to reason that we design for 25mg/Nm$^3$ or better. This is possible essentially & achieved economically with membrane technology than other options.

5.2 Cement Grinding System:

Now let us look at the progress of grinding system processes, and review the progress of APCT. This will clarify why simultaneous advancements in APCT were necessitated.

Past (First system/old systems): Early on there were open circuit grinding systems and APCT was not even as important. Then closed circuit grinding with old style separators came into existence. The separators and mill needed venting into a FF. The FF typically used to be reverse air or shaker type systems with very low air-to-cloth ratio. Typical fabric media was cotton and wool. These had major maintenance problems. These FF used to be a nightmare for the maintenance group at the plant.

Then came the High efficiency Cyclone Separators around the early 80s (Cyclo-Pol® and then O-Sepa® Sepol®, Sepax® etc.) These were introduced around the same time as the roller presses. However High Efficiency separators caught on popularity like a wildfire. One of the reasons they became popular so quickly was their flexibility for use on multiple mills without losing efficiency. Whenever cement plants used these to cool the cement as well as classify, they used large FF as the main product collector. So the FF became an integral part of the process rather than an auxiliary part. Introduction of GORE® membrane filters in these FF also allowed further optimization of the system and steady state conditions. These FFs with GORE™ membrane provided longer than 3 years of uninterrupted service, with lower than 150 mm WG ΔP despite as high as 1000 g/m$^3$ inlet dust load.

Present Status: In India, Ball mill and Vertical mills are both prevalent today. In few old cement plants, ESP is still in use. For blended cement other than fly ash, the industry trend is to go for vertical mill. When fly ash is used for blending & fed in the separator / mill outlet, ball mill is preferred. Outside India, Vertical mill is the standard.
Use of Blast Furnace Granulated Slag: Use of Ground Granulated Blast Furnace slag in cement increased the quality of cement. However, the grinding of slag provides new challenge because of moisture and hardness of slag. This forced new innovation in roller mill and roller press technology. Some of the new types of mills (like HORO Mill and CKP mill) also came into market place for use just like roller mills with specific advantages. The slag grinding brought more moisture into FF causing more problems. The PTFE membrane filter bags can handle very high levels of moisture.

Fly-ash addition: The second area was mixing of fly-ash and pozzolanic mixtures to cement. These brought in another problem on the FF. The irregular and fine particle size of these material caused additional burden on the FF. Use of GORE™ membrane again provided the benefits to overcome some of the problems related to high ΔP and emissions.

Future Trend:

Based on the process of total dust collection in the FF in addition to finer dust size, varying dust particle size distribution, high moisture, need for more stable static pressure at the mill outlet, the future trend will be towards more use of PTFE membrane filters. The environmental need of meeting 50 mg/Nm³ emission regulation and future possible target of 25 mg/Nm³ emission also points towards increased use of PTFE membrane filters.

5.3. Coal Grinding System:

Now let us look at the progress of grinding systems for coal, and review the progress of APCT. The improvements achieved in cement grinding are also applicable to coal grinding. In addition to coal, Lignite and Coke are also being used in some parts of the country as fuel. Hence, the grinding system should be flexible enough to grind coal, lignite, coke and some combination of these fuels. The process in all the new cement plants is using vertical mills for grinding & large FF as the main product collector. So the FF became an integral part of the process rather than an auxiliary part. Most coal grinding plants are still using non-membrane anti-static mixed felt (50/50 blend of polyester and acrylic) or 100% acrylic felt filter media with filtration velocity (air to cloth ratio below 1 m/min). Typical performance with these non-membrane filter media is 40 to 80 mg/Nm³ emission rates, 120 to 200 mmwg pressure drop and 1 to 2 year bag life.

Some plants have switched to GORE® membrane filters in these FF to achieve further optimization of the system and steady state conditions. These FFs with GORE® membrane filters provided longer than 5 years of uninterrupted service, with lower than 150 mm WG ΔP despite as high as 500 g/m³ inlet dust load and less than 30 mg/Nm³ emission rate.

New coal grinding systems can take further advantage by using GORE™ membrane in the FF and achieve higher air to cloth ratio. This allows the project team to design FF with better quality filter bags at same or lower initial capital cost and reducing the annual maintenance cost of the coal grinding system.

Reduced chances for Explosion:

Gore uses highly conductive fibers which are blended throughout the felt to make the felt electrically conductive. The Static decay time for the Gore bags is less than 0.01 sec. The membrane bags are almost dust free after every pulsing. Thus, the dust accumulation on the bag is drastically reduced. Both these factors will reduce the fire and explosion chances.
Other Applications where PTFE membrane bags can be profitably used are areas having high dust load, higher ambient moisture, varying temperatures during operation, difficult location for maintenance, such as,

- Packing Plant
- Bulk receipt & Bulk dispatch stations of powders (Cement / Flyash)
- Silo dusting & Silo recirculation systems.

6. LONG TERM CASE STUDIES

To prove the approach, we have shown below some successful field trials with detailed data. For protection of our customers, the names of the customers have not been mentioned.

6.1. Reverse Air Kiln baghouse (RABH):

16 compartment reverse air type Thermax bag house for Cement Kiln/Raw mill venting in India.

**Problem**

Customer decided to increase the production capacity by increasing the pre-heater fan capacity. For this, the bag house had to handle higher airflow maintaining the same pressure drop across the bag house.

**Solution**

Installed Gore® Filter Bag (Acid resistant fiber glass filter Bags) in 4 compartments (i.e. 25%) in July 1997.

**Results**

The results are better than the expected and with raw mill down, the operating data are as under:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before installing Gore® Filter Bags</th>
<th>After installing 25% GORE® Filter Bags</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiln feed rate, TPH</td>
<td>208</td>
<td>217</td>
<td>4.3↑</td>
</tr>
<tr>
<td>Airflow, m³/hr</td>
<td>527003</td>
<td>604567</td>
<td>15↑</td>
</tr>
<tr>
<td>Pressure drop, mm wg</td>
<td>190</td>
<td>170</td>
<td>10.5↓</td>
</tr>
</tbody>
</table>

The first lot of bags have completed more than 12 years without loss of any bag. The customer carried out plant upgradation from 3300 TPD to 4500 TPD in phases. The customer has replaced additional 21 modules in two kiln baghouses in year 2000. The second lot of bags have also completed 9 years of trouble-free operation.

6.2 Cement Mill case study:

A Pulse-jet bag filter with 450 bags installed for venting of ball mill.

**Reason For Selection Of Gore Bags**

Management decided to use Gore bags so that the mill production will not be affected due to frequent choking of conventional bags and to get the lowest emissions with longest un-interrupted bag life. To reduce the total cost of using Gore bags, only 450 Gore bags were installed in the bag filter, which was designed for 630 bags. Thus, 180 holes were blanked off. These can be used in future, if the production
rate needs to be increased or finer quality of cement (PPC) needs to be milled. Gore provided complete filter design, inspection and bag installation services.

**Filter Design**

Filter Media : Gore® Filter Bag (acrylic felt, 14 oz/yd²)

|  |  
|---|---|
| Air flow | 1083 m³/min |
| Air to cloth ratio | 1.41 m/min |
| Dust load | 800 gm/Nm³ |

**Results**

- The bag filter is operating at less than 110 mm wg DP across the bag filter at full load. The filter bags were replaced with a new set of Gore bags after completion of more than 7 years of trouble-free operation with no loss of bags.
- Gore bags are operating at less than 30 mg/Nm³.
- No maintenance required on the system, due to bags.
- System reliability is very high.

**6.3. Coal Mill case study :**

A Pulse-jet bag filter with 1350 bags installed on a vertical coal mill for total dust collection in the bag filter.

**Reason For Selection Of Gore Bags**

This is a new 7000 TPD plant and management decided to make smaller baghouse with Gore bags so that baghouse cost was only marginally higher than conventional bags but the baghouse performance would be much better compared to conventional bags with regard to bag life, maintenance and emissions.

**Filter Design**

Filter Media : Gore® Filter Bag (anti-static acrylic felt, 475 g/m²)

|  |  
|---|---|
| Air flow | 3347 m³/min |
| Air to cloth ratio | 1.51 m/min |
| Dust load | 393 gm/Nm³ |
| Bag size | 152 mm x 4267 mm |

**Results**

- Data as on 09.07.02 : Air flow : 3489 m³/min, DP across bags : 85 mm wg.
- The filter bags were replaced with a new set of Gore bags after completion of more than 7 years of trouble-free operation with no loss of bags.
- Gore bags are operating at less than 30 mg/Nm³.
- No maintenance required on the system, due to bags.
- System reliability is very high.
7. CONCLUSIONS

From the trends described it is apparent:

- **APCT** is not an auxiliary equipment any more. It is an integral part of the process as far as the cement kiln, cement mill, and coal mill exhausts are concerned.
- People’s perception of the environment is drastically changing. The black and polluted chimney does not equate industrial growth explosion and modern developments. It equates irate residents and heavy protests resulting in questions about very survival of the industry in the region.
- The Government is also responding to the modern trends by tightening the environmental regulations.
- Filtration technology is definitely shifting its balance from ESP to FF in most processes in Cement Industry.
- The advances in filtration technology and surface filtration have kept pace with modernization of the cement industry.
- PTFE membrane filter bags have been applied very successfully across the board to all the main cement processes. Majority of the new Kiln baghouses are using PTFE membrane technology. The cement and coal grinding processes are slowly shifting to PTFE membrane technology. Over the next fifteen years, most of the cement and coal grinding systems will start using PTFE membrane technology.
- PTFE membrane filters have increased the reliability of the FF in the industry.
- These filters allow the cement plant controller better predictability and better handle on the cost. This, when coupled with their ability to operate at higher air-to-cloth ratio thus requiring smaller size equipment, makes them uniquely suitable for cement industry.
- This technology can be applied to new projects as well as existing projects with similar success.

Authors humble request to the cement manufacturers is “Give the due importance to type of filter media, as the FF is no longer the pollution control equipment: it is a key **PROCESS** equipment”.

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