The key challenges in cement kiln bag houses are high dust loading of the filter bags, high temperatures that degrade the filter fabric and applications with high filter air-to-cloth ratios (ACR) that blind filter bags and cause abrasion and delamination of membrane bags. The result of these effects is loss of production due to excessive plant downtime for the repair or replacement of filter bags, rising operating costs that result from increased filter pressure drop, and emissions excursions.

Pulse jet fabric filters are commonly used on cement kilns to control particulate emissions. The baghouse has high collection efficiency and consistently low emissions with fluctuating load and fuel properties when fitted with high performance filter media. The key to efficient and long-term baghouse operation is proper selection of the fibres used in the filter media.

Baghouse design basics
The principles of baghouse operation may be straightforward but the design of a baghouse is complicated. Baghouse systems are expected to achieve optimum removal of particulates in the exhaust gas stream - from submicron to several hundred microns in diameter - with collection efficiencies in excess of 99.9%. Baghouse designers must carefully evaluate gas volumetric flow and velocity, static pressure drop, and ACR (m/min). Fuel combustion products, operating temperature, dust loading, physical characteristics of the particulates and the dew point of any condensables in the gas stream all play a vital role in the choice of the fabric material and bag design, particularly in plants that use waste-derived fuels.

Particulate capture occurs on the surface of fabric filter units, as the gas passes radially through the filter fabric. The clean gas is vented to atmosphere (See Figure 1). Exhaust gas is drawn through the filter media, which forms a dust layer on the surface of the fabric media. This effect steadily increases the filtration efficiency at the expense of increased pressure drop across the unit. When the prescribed pressure drop is reached, the filter bags are cleaned, either on- or off-line. Particulates captured on the surface of the filter fabric are typically separated by a short upstream burst of high pressure air several times each hour to eject the dust particulates from the filter media surface. The particulates are subsequently collected in a hopper found at the bottom of the baghouse enclosure for disposal or recycling.

Dust collection plays a critical emissions reduction role for safe and efficient operation of cement kilns. There are several challenges to be overcome. This article looks at how high-performance filter media helped overcome issues at three different cement plants.
distribution is also often the cause of membrane damage. The result is reduced membrane life, increased pressure drop, and emissions excursions.

**Filter media fundamentals**

P84® fibre is unique among polyimide (PI) fibres. It is the only PI fibre produced with an irregular, multilobal shape. Each fibre has its own unique shape and is formed naturally as part of the production process. The irregularity of the P84® fibre cross section ensures that, even when charged with dust, the filter material maintains a high porosity (See Figure 3).

A critical aspect of the filter material used in cement plant baghouses is also the fibre surface area. Fibres with high cross section irregularity, such as P84®, have larger surface area than fine circular fibres for a given filter volume. Thus the travel path through irregularly-shaped filter media is also more complex. This is instrumental in the formation of a stable yet porous dust cake, particularly during cleaning.

Low velocity contour zones are created when flue gases pass by P84®-based felt fibres. P84® fibres provide low and zero velocity zones that allow dust to slow down and collect on the fibre surface. These zones are quite extensive compared to round fibres. The structure of the filter media is transferred to the structure of the dust cake and the dust cake formed by the P84® multilobal fibres is irregular and porous. The flow-lines are affected to a lesser extent if compared to the round fibres dust cake.

P84® fibre filter media also prevents the penetration of fine dust particles deep into the needle felt due to its excellent filtration properties. The unique multilobal profile of P84® fibres ensures that even fine particles are collected and no dust can penetrate the needle felt, even at the very high dust loads typically found in cement plants (See Figure 4). This has
important benefits in terms of low particulate emissions, low pressure drop across the bag house, low compressed air pulsing volume and rate, and the capacity to deal with a high dust loading.

The most important dust collection activity takes place in the permanent dust cake formed on the surface layer. The dust cake formed by multilobal fibres is stable and part of it remains attached to the felt during the cleaning (See Figure 5). Without a permanent dust cake, small particles can pass through. More importantly, a stable, porous dust cake is also required to prevent blinding of the felt and excess emissions. A standard 2.2 dtex P84® fibre has 65% more surface area than a comparable round fibre size. This increased surface area allows much more dust to attach to the surface area when compared to a round fibre, keeping the felt clean over time. If small particle sizes or strict emission limits are a concern, finer P84® fibres with even higher surface areas are available.

Three case-studies

The typical cement plant will experience many physical changes over its operating life. Common examples are a fuel switch, change in air heater performance, installation of new emission control equipment, or perhaps an increase in production. Each of these changes can increase the baghouse ACR and may cause poor gas distribution in certain modules within the baghouse. The ACR for membrane bags is limited to 1m/min and round fibre bags is limited to 1.18m/min. P84® bags can tolerate air to cloth ratios of 1.4m/min providing 20-30% more capacity without increasing the physical size of the existing baghouse. The following three case studies illustrate the operating cost and reliability advantages of using P84® in baghouses installed on cement plant kilns. The first case study is a cement plant in Oman that experienced an increase in emissions when production rates were increased. The second case study is a cement plant in India that experienced emissions excursions due to membrane failure in its baghouse. The final case study, from Poland, examines the impact on baghouse membrane selection when the cement kiln is fired by an alternative fuel.

Oman case-study

In our first case study, a cement plant increased its production rate, which led to a high ACR in the kiln baghouse that used PTFE/woven glass bags and a resultant increase in plant particulate emissions (See Figure 6). With increased production, the baghouse ACR increased to 1.42m/min. The plant owner changed suppliers of the woven glass bags and purchased new cages with the new bags. The plant experienced high failure rates with the new bags, with some failures occurring within a few months or even weeks.
of installation. This led to unexpected plant shutdowns to replace bags. The failures began with a few holes on the cage side or from outside. Once dust migrates to the clean side of the bag, more abrasion occurs, which then causes more failures. The plant used almost an entire spare set of bags during 2015 as replacements for failed bags. The plant frequently violated local particulate matter emission limits.

In May 2016, the woven glass bags were replaced with bags constructed from P84®. For the first 14 months of operation there were no problems reported. After 14 months the plant owner reported that in one chamber several bags had failed. The owner was able to isolate that chamber to control emissions. An inspection of the chamber found the failing bags were touching each other or reinforcing structures within the chamber. There were 33 damaged bags out of 4368 used in the baghouse. The positions of the failed bags were noted in anticipation of a more thorough inspection during the annual maintenance outage.

The annual inspection found that approximately 1000 7m-long bags were installed in 6m-long cages. The long cages were mixed with bags and cages slated for another unit at installation. However, not a single bag was damaged during 14 months of operation with the short cages and there were no emission violations during that period.

The short cages were subsequently replaced with the correct size cages (without replacing the bags). The plant completed the next two years of service with the P84® bags without incident and particulate emissions that were consistently well below local standards. The bags are expected to complete the estimated 3-5 years of service before replacement is necessary. Also, the Line 3 woven glass bags were replaced with P84® in 2017 and the owner reports that no problems have been experienced.

**Case-study in Andhra Pradesh, India**

The PTFE/woven glass membrane bags in a 3500t/day kiln began to fail, causing increased particulate emissions, often above local limits, after six to nine months of operation. The ACR of the plant was 0.94-1.15m/min.

The damaged bags were randomly distributed within the baghouse, which complicated the failure analysis. The baghouse and cages were made from mild steel. It was determined that operation at relatively low temperatures produced corrosion of the cages and the clean gas plenum. The damage also occurred randomly along the bags in the form of small holes at the point of contact of the bag with the cage wires. Finally, the bags started tearing along the marks of the vertical cage wires. Bags from different suppliers did not show any significant improvement in performance.

The analysis concluded that early bag failure was not a result of inferior bag material quality but rather the suitability of the bag material for this baghouse. In particular, corrosion of the cages created too much wear to the woven glass fabric. Once the bags started to fail, dust was carried to neighbouring bags through the clean gas plenum, which increased abrasion and the number of failing bags.

In March 2016 all 2160 filter bags were replaced with P84® fabric bags and there have been no observed failures since.

**Lafarge kiln/raw mill case-study in Poland**

Reducing fuel cost is the goal of every cement plant. One approach to managing fuel cost is to use an alternative, less expensive fuel. However, a fuel switch to refuse-derived fuels can create problems for bag life spans, as it did for this Polish plant.

Filter bags constructed with P84® were installed in Line 2 at this plant from its 2005 plant commissioning. Since that time the pressure drop has remained less than 995.36Pa (inlet to outlet) and emissions remained well below the local standard. The ACR was 1.06m/min. The bag life was estimated to be five years and the life of the P84® bags has historically been between four and five years since startup.

The bag house of Line 3, a copy of Line 2, was commissioned using PTFE/woven glass membranes and the bags experienced higher pressure drop than the bags used on Line 2 from startup. More frequent cleaning accelerated bag wear and a high rate of premature bags failures were experienced, as well as emission limit exceedances. The maximum bag life was three years.

The bag damage generally occurred in the bottom region, where black discolouration was discovered at the surface and beneath the membrane. Further analysis found unburned hydrocarbons were blocking the membrane. In 2016, the woven glass bags were replaced with bags made from a PTFE-P84® blend because the temperature in Line 3 is higher than in Line 2. The new bags continue to perform well after two years of service with a pressure drop 249Pa lower than before.