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# CERAMIC FILTER ELEMENTS FOR EMISSION CONTROL AND NOX REDUCTION AT HIGH TEMPERATURES

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## Summary

Glass furnace off gases are characterised by being at elevated temperature, depending on the level of heat recovery, and carrying a mixture of pollutants. Chief among the pollutants in glass furnace off gas are particulate, oxides of sulphur and oxides of nitrogen. A number of well established techniques exist for treating these pollutants, either individually or in combination.

An emerging technology for glass furnace off gas clean up is the employment of low density ceramic filter elements. Ceramic filter elements are extremely efficient and work well in combination with a dry scrubbing agent for acid gas removal. Further, given the refractory nature of the medium, the filtration temperature can be maintained at a suitable level for catalytic treatment of NOx.

The Clear Edge catalytic ceramic filter element, Cerafil TopKat, offers deNOx functionality as well as efficient particulate and acid gas removal. Thus the major pollutants emitted by a glass furnace can be treated in a single piece of equipment. The technology, apart from major environmental performance benefits, offers the possibility of substantial savings both in monetary terms and space utilisation, the latter being of paramount importance for many existing glass manufacturing sites.

Ceramic filters offer the potential for phased implementation of pollution abatement equipment. In the first instance a filter based around standard filter elements can be installed. This phase provides particulate abatement, acid gas removal (with a sorbent) and sufficient temperature for future NOx control. At the point when NOx control is required the end user has the choice to opt for selective catalytic reduction (SCR) technology or retrofit the ceramic filter with Cerafil TopKat filter elements. The most appropriate choice can be made on the basis of economic and technical considerations. The attractions of phased introduction are the ability to meet abatement requirements without unnecessary or premature expense.

**Keywords:**
Ceramic filter, gas filtration, hot gas filter, high efficiency, catalyst, DeNOx

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## 1. INTRODUCTION

Gas filtration employing rigid low density ceramic filter elements (aka candles) is now a well established technique. The product was initially developed in the mid 1980's in response to the need to clean hot dirty gas down to levels of particulate matter sufficiently low to meet new environmental legislation. The earliest applications were rather specialised but application soon broadened out to a wide variety of duties where the benefits of the product could be exploited. This process was accelerated by the introduction of monolithic elements in the early 1990's.

Given the benefits of ceramic filters duties are focussed on the need to filter gas, either process or off gas, at a high or variable temperature while delivering high particulate removal efficiency. Key applications therefore include waste incineration and gasification, metals processing, mineral processing and glass melting. The majority of duties are air pollution control (APC) however there is an increasing uptake of ceramic filters for process filtration or product recovery duties.

In recent years the demands on gas filtration media have strengthened while legislative emission limits have tightened. These trends have precipitated an ongoing development program aimed at providing a range of ceramic elements tailored to meet the demands of industrial end users.

Cerafil TopKat (patent granted 2007) represents a revolutionary development in the technology. The element, jointly developed with Haldor Topsøe A/S, incorporates an integral catalyst capable of significantly reducing dioxin, NOx and volatile organic compound (VOC) emissions.

## 2. CHARACTERISTICS, BENEFITS AND APPLICATION

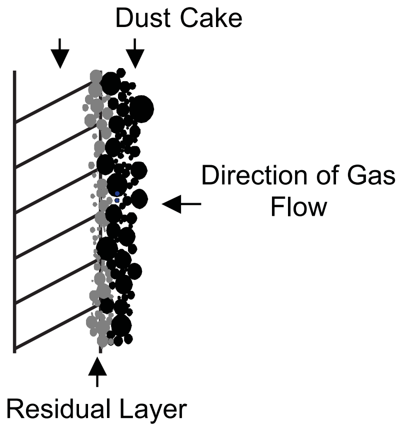
Low density ceramic elements (ceramic elements) are produced in a variety of sizes from 60mm outside diameter and 1 metre long up to 150mm outside diameter and 3 metres long. The larger sizes can be employed like fabric bags in new equipment and retrofitted into existing plant. Ceramic elements are manufactured from ceramic or mineral fibres, which are bonded together with a combination of organic and inorganic binders. Elements are formed into a shape which incorporates an integral mounting flange resulting in a rigid, self supporting structure.

Ceramic elements take the benefits of fabric bag filtration a stage further by offering excellent filtration efficiency coupled with the ability to operate at elevated temperatures. This latter benefit is utilised across a broad spectrum of industrial applications where there is a requirement to filter gases which are at a high or variable temperature or where temperature surges can occur. An otherwise stable operation can suffer from temperature surges, which can be very damaging to conventional fabric media. When such events occur it is not just the cost of the media which has to be taken into account; the costs associated with an unscheduled filter plant shutdown can also be high.

The benefits to the end user of high or elevated temperature filtration include-

- Move away from the temperature limitations imposed by fabric bags
- Reduced requirement for gas dilution results in smaller plant
- Acid and water dew points can be avoided thus minimising plant corrosion
- The gas temperature can be maintained for optimal deNOx
- Elevated temperature gas cleaning gives the potential for heat recovery from clean gas
- Higher stack exit temperatures increase gas buoyancy and therefore reduce the risk pf plume grounding

High filtration efficiency is a key benefit associated with ceramic filter elements. This results from the development, during the early stages of operation, of a protective dust layer on the element surface which promotes cake filtration (figure 1). Cake filtration is essential to long term performance of a barrier filter medium. The rigidity of ceramic elements further promotes cake filtration since the protective dust layer is not compromised during cleaning.




Ceramic elements are employed on duties where the benefits, described earlier, of the medium can be effectively utilised. This is typically duties where high capture efficiency is required in combination with temperature resistance. However it is worthwhile stressing that ceramic elements are not simply a "hot gas filter". Although ceramic elements can be and are applied in high temperature filtration duties they are equally applicable where the filtration temperature regime is variable or subject to surges which could damage conventional fabric media.

## 3. CATALYTIC CERAMIC FILTER ELEMENT

### 3.1 DEVELOPMENT

Clear Edge, in collaboration with Haldor Topsøe A/S, have developed a catalytically active ceramic filter element. The filter element, named Cerafil TopKat, incorporates an integral catalyst formulated to oxidise dioxins and reduce NOx, the latter in combination with ammonia or urea injection. The catalyst is also effective at oxidising VOC's where the operating temperature regime is sufficiently high (220$^{o}$C +).

The catalyst material is a proprietary mixture of oxides which is incorporated into the body of a filter element in such a way as to ensure even distribution. Figure 2 below shows an EDAX plot (energy dispersive analysis by x-ray) of the catalyst distribution across the wall of a TopKat element.

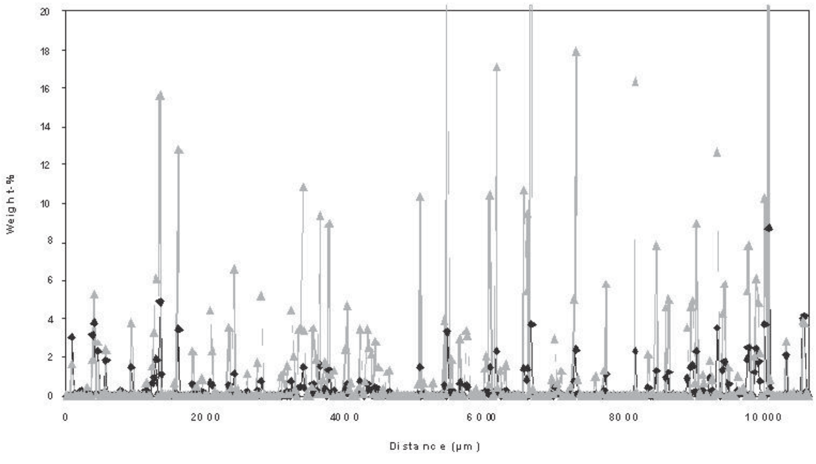



Figure 2 Catalyst distribution plot through 10mm thick element wall

As can be seen, the mixed oxide catalyst materials, represented by the two plots, are both distributed throughout the depth of the filter body thus ensuring maximum possible residence time. Catalyst efficiency is further enhanced by virtue of the fine nature of the material employed. This application of nano technology ensures that the diffusion restrictions associated with conventional catalyst technology are eliminated thus ensuring optimal removal efficiencies. Figure 3 shows an SEM image of a portion of filter body. The catalyst particles can be clearly seen coating the fibres within the fibre matrix.


Figure 3 SEM image of filter body

3.2 PERFORMANCE

TopKat builds on the efficiency and temperature capability of ceramic elements by adding the ability to dramatically reduce dioxin, NOx and VOC emissions. As these species increasingly become the focus of environmental legislation technically and economically effective means of controlling them need to be developed.

Selective catalytic reduction (SCR) can be employed for glass furnace off gas NOx reduction, particularly where primary controls are unable to meet local legislative requirements. The technology is effective but there are drawbacks. SCR catalysts can be poisoned by particulate matter carried over from upstream abatement plant. This is especially critical where electrostatic precipitators (ESP's) are employed since emissions of the order of 20 – 30 mg/Nm$^3$ are typical, even higher during upset conditions. Cerafil TopKat is a potential solution providing the necessary removal efficiency through a filter plant with the minimum of ancillary components.

3.3 IMPLEMENTATION

Ceramic filters offer the potential for phased implementation of pollution abatement equipment. In the first instance a filter based around standard filter elements can be installed. This phase provides particulate abatement, acid gas removal (with a sorbent) and sufficient temperature for future NOx control. At the point when NOx control is required the end user has the choice to opt for selective catalytic reduction (SCR) technology or retrofit the ceramic filter with Cerafil TopKat catalytic filter elements. The most appropriate choice can be made on the basis of economic and technical considerations. The attractions of phased introduction are the ability to meet abatement requirements without unnecessary or premature expense.

3.4 CASE STUDY

A Cerafil TopKat trial has been carried out at a European float glass line in order to demonstrate the technology. A schematic of the pilot installation is shown below (figure 4)-

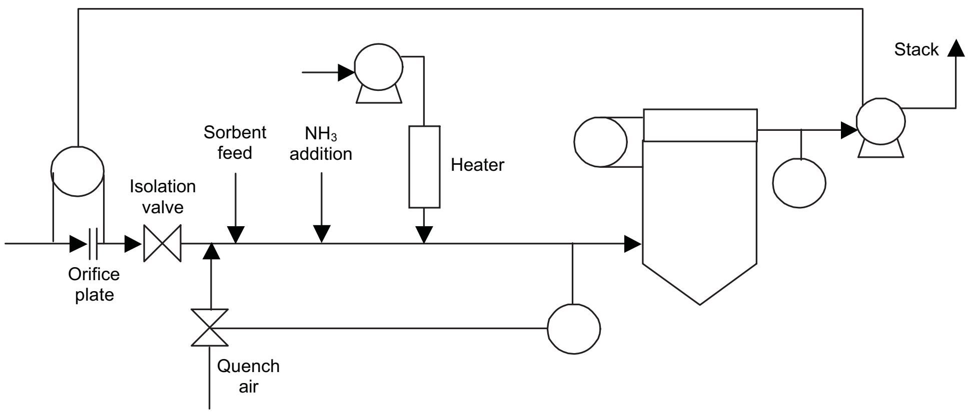



Figure 4 Schematic diagram of pilot filter installation

Table 4 Filter parameters

| | | |
|---|---|---|
| Element type | | TopKat-3000 |
| Quantity | | 40 |
| Surface area | $m^2$ | 56 |
| Filtration temp. | $^oC$ | 350 |
| Gas flow | $Nm^3/h$ | 1800 |
| NOx inlet concentration | $mg/Nm^3$ | ~1200 |
| NOx outlet concentarion | $mg/Nm^3$ | <200 |
| Face velocity | m/s | 0.02 |
| Pressure drop | KPa | ~1.75 |

Exhaust gases exiting the furnace first pass through a boiler plant which drops the gas temperature to between 400 and 470°C. The filtration temperature was controlled by the addition of heated or quench air. Volume flow through the plant was adjusted by means of a frequency inverter on the fan which in turn was controlled by the orifice plate flow measurement.

The purpose of the trial was to determine the flow/pressure drop/temperature characteristics of the filter media along with NOx reduction efficiency. The trial output has allowed for the future scaling of full scale plants while a NOx reduction in excess of 80%, down to target levels, was achieved.

## 4. CONCLUSION

The employment of low density ceramic filter elements for pollution control and product recovery applications is now well established. The principal benefits of ceramic elements are high filtration efficiency and high temperature capability. These benefits can most effectively be utilised to treat the gases associated with high temperature processes where high filtration efficiency is required. The latter requirement is usually as a result of stringent emissions legislation.

Demands on filtration technology and therefore filter media have increased in recent years particularly as a result of tightening emissions legislation. In response to these demands low density ceramic filter technology is advancing with the introduction of new formulations and geometries.

Cerafil TopKat represents a revolutionary advance in ceramic filter technology. The new element extends ceramic filter capability by incorporating an integral catalyst for dioxin, NOx and VOC removal. The product has already exhibited excellent NOx removal ability both in pilot and full scale plants. Empirical data collected to date has demonstrated that it is possible to effectively combine filtration capability with catalytic activity.

The development of a catalytic low density ceramic filter element has demonstrated that low density ceramic filter technology can progress to meet the new challenges posed by strengthening environmental legislation. Where a duty demands the ability to operate at a high or variable temperature and control a range of prescribed pollutants ceramic filter technology provides a viable solution.

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