# CERAMIC SAVIOUR

**M. Giavazzi, Boldrocchi Srl, Italy,** weighs up the advantages and disadvantages of operating high temperature filtration using ceramic candle filters instead of typical felt bags.

As environmental regulations become increasingly stringent around the world, and the internet and social media are able to spread embarrassing news of environmental non-compliance within minutes, oil and gas companies, similar to those in other industries, are feeling the need to ensure conformity (often with expensive upgrades to systems) while finding ways to reduce OPEX. One technology that can help producers to reduce OPEX in their air pollution control systems is filtration using ceramic filters. This technology provides optimal filtration efficiency while withstanding high operating temperatures and is particularly useful when looking to increase heat recovery and/or comply with stringent emission regulations. Ceramic filters also require less energy, fewer cleaning cycles and reduced

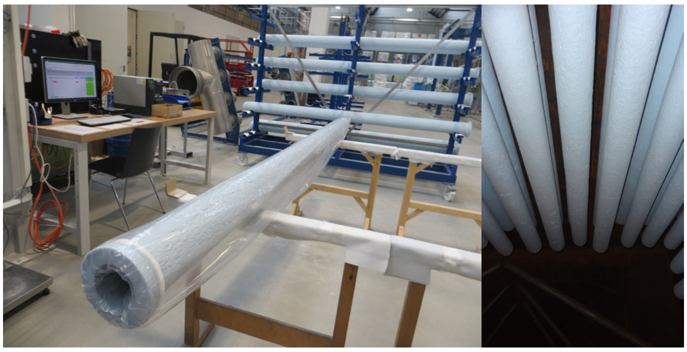

**Figure 1.** Ceramic candle filters or elements can withstand constant temperatures of up to 800°C.

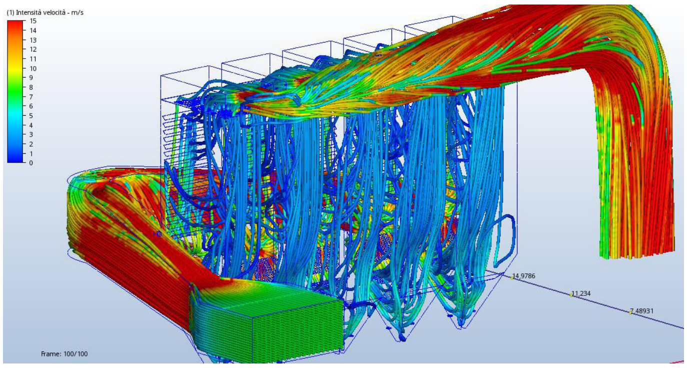

**Figure 2.** The velocity profile from a CFD study of a tailor-made Boldrocchi ceramic candle filter. This was a retrofit project.

**Figure 3.** Boldrocchi's ceramic candle filter pilot plant.

**Figure 4.** Flowrate setting and differential pressure measurement.

downtime, while foregoing the need for cooling systems.

This article describes how it is possible to operate high temperature flue gas filtration using ceramic filters (or elements) within traditional bag filters, instead of using typical felt (or similar media) bags. Boldrocchi's ceramic candle filters are also described, as is a case study of a substantive project (eight filters) in an integrated gasification combined cycle plant.

## Ceramic elements for high temperature filtration

The use of filter bags for industrial gas dedusting is currently the most common solution. The porous felt (or other typical material) performs well in capturing dust, offering low residual emissions and a low system pressure drop. However, in many industries, gas cooling is required before dedusting as the filter bags' maximum allowable filtration temperature is far below the flue gas temperature. Moreover, precious flue gas heat is often lost as heat recovery systems have difficulty keeping up with high dust gases.

Ceramic elements (Figure 1) are an interesting alternative. They offer the following:

- The ability to withstand continuous operating temperatures of up to 800°C and peak temperatures of up to 1000°C.
- High efficiency, achieving emission levels of up to 1 mg/Nm$^3$ and easily handling fine dust.
- No need for gas cooling before filtration and, therefore, no water consumption or additional dilution of the gas.
- Possible heat recovery after the bag filter, as heat exchangers can operate problem free due to lack of dust.
- The use of traditional bag filter technology (same general design, gas distribution, cleaning system).
- No need for filter bag cages as the ceramic filters are made of a high density self-supporting material.
- Extremely lightweight material, reducing the weight on the bag filter's cell.
- High chemical resistance: they can be used with a wide range of common reagents and sorbents to remove heavy metals, nitrogen oxides ($NO_X$), acid components and dioxins.
- 100% spark resistance and non-flammable.
- High permeability, which means low pressure drop.
- An environmentally friendly and safe material as they are non-carcinogenic.

There are, of course, some limitations to consider, mainly related to process conditions:

- The hydrogen fluoride (HF) content of the flue gas must be controlled.
- Condensation must be avoided (a pre-heating procedure is always required).

- Operation must be above dew point.
- Can velocity must be limited to avoid possible damage.
- CAPEX is higher than with traditional filter media (however, OPEX is reduced due to, amongst other things, the absence of cooling devices).
- Ceramic elements are fragile, requiring specific attention during transport and assembly.
- Ceramic elements have a limited length, meaning an increased bag filter footprint.

## Designing a ceramic candle filter

As in traditional bag filters, the design of a ceramic candle filter depends on filtration parameters, including gas velocity and composition. Detailed calculations must be made as conflicting benefits must be considered. While a higher filtration velocity reduces CAPEX (smaller filters and fewer ceramic elements), it increases pressure drop and reduces the lifetime of the candle elements. A lower filtration velocity also increases filtration performance (reducing residual emissions) and is required to comply with stringent emission limits.

Conservative design guidance is therefore needed, using computational fluid dynamics (CFD) and, as discussed further in this article, a physical model is optimal to test theoretical calculations. The goal is to offer each specific project a tailor-made design with homogeneous gas and dust distribution, i.e. no peaks of gas or dust and an equal operation of each part of the bag filter (Figure 2), so as not to cause premature wear to one part of the ceramic elements and to ensure optimal effectiveness.

Design considerations and objectives were each evaluated on a case-by-case basis:

- Increasing the bag filter size will allow the gas to expand and distribute evenly before reaching the ceramic elements. This will reduce the gas velocity inside the bag filter and optimise interstitial velocity (depending on dust characteristics).
- High dust situations require a dual-phase CFD analysis to increase dust pre-separation before reaching the ceramic elements.
- A variable 'differential pressure set-point' can be calculated using special algorithms to optimise filter performance in some cases.
- A lower cleaning frequency will avoid peak dust emissions during cleaning shoots.
- Cleaning systems with compressed air pressure adjustment are preferable, so as to be able to adjust the snap back pressure wave. This removes the filter cake partially or completely.

## Undertaking physical tests on ceramic filters

Boldrocchi is currently carrying out targeted R&D on its ceramic candle filters. A new pilot plant has been built at its facilities (Figure 3) to study ceramic elements with different kinds of dust and multiple process conditions.

The physical model is composed of a casing with no.4 ceramic candles (150 mm dia. x 300 cm long), a clean chamber with cleaning blow pipes, a compressed air system for cleaning with a modular design (in order to easily allow the testing of different kinds of valves and tanks), a dust supply and recirculation system, a fan with flow regulation and a cleaning control board.

For each project, the R&D team undertakes a variety of tests (Figure 4). Their objectives include the following:

- Defining the optimal size for the cleaning valves, dependent on the dust's specific properties, even if sticky or very fine dust (Figure 5).
- Keeping the valve opening time and the compressed air pressure as low as possible to reduce energy consumption and increase the ceramic elements' lifetime.
- Ensuring the pressure drop decreases to initial values (or similar) after the activation of the cleaning system.

In their tests, they ensure that the gas flowrate is regulated in order to obtain the same filtration velocity as in the 'real' filter. The tests also measure the differential pressure of the clean ceramic elements at specific filtration velocities (Figure 5) and the dust is dosed in order to increase the differential pressure. Once that has been achieved, the teams then test the capacity of the system (as configured) to maintain a constant pressure drop, while dust is continuously fed into the system (Figure 6).

## Case study: filter in an integrated gasification combined cycle project

Boldrocchi's ceramic candle filters were recently installed in an integrated gasification combined cycle (IGCC) plant. This is a complex plant (Figure 7), where a solid or semi-solid fuel is converted into a synthetic gas (syngas) that can be used as primary fuel in a combined cycle power plant. Ceramic candle filters have two potential applications on this type of plant.

An IGCC plant is generally divided into the following major systems:

- An air separation unit (ASU) to produce the oxygen used in the gasification process.
- The gasification system, in which the syngas is produced, cooled and cleaned. The produced soot is routed to the heavy metals recovery system.
- The power island, where the syngas is fed to the gas turbine within the combined cycle. The hot flue gas discharged by the gas turbine is used to produce high pressure steam through a heat recovery steam generator (HRSG) that feeds a steam turbine.
- The heavy metals recovery system, where saleable metals from the soot produced during the syngas cleaning process are recovered.

At the IGCC plant in this case study, multiple special furnaces were used to burn carbon residuals from the gasification process soot and to recover saleable dust with a high content of chrome and

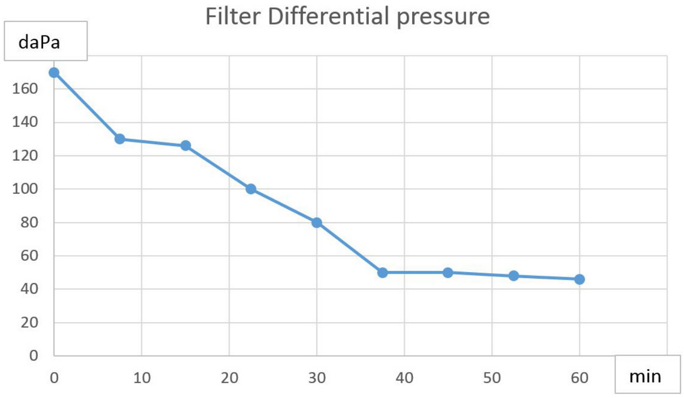


**Figure 5.** Pressure drop reduction after cleaning system activation.

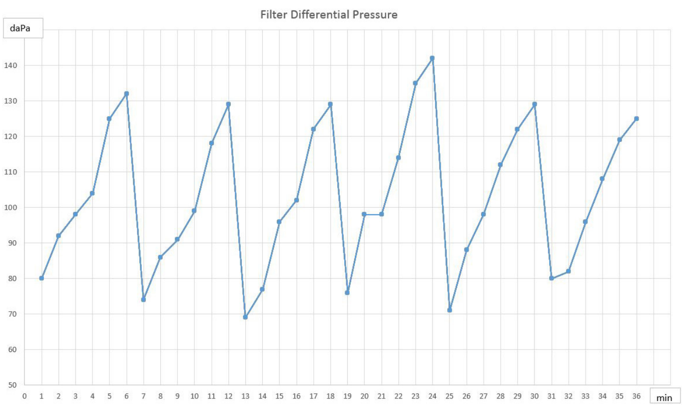


**Figure 6.** Pressure drop with dust continuously fed into the system.

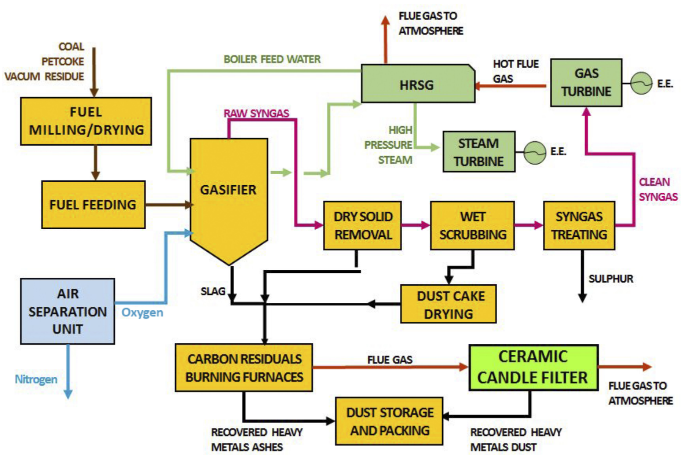


**Figure 7.** Integrated gasification combined cycle (IGCC) plant.

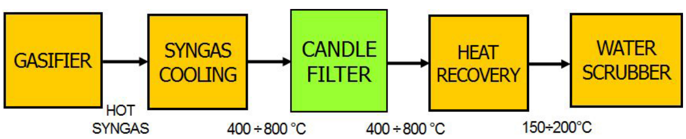


**Figure 8.** Potential use of ceramic candle filters as syngas treatment, depending on the application and on the type of fuel fed to the gasifier.

vanadium. Boldrocchi's filters filter that dust – with the high content of heavy metals – from the furnaces' flue gas before being released into the atmosphere. Ceramic elements are ideal as filtering media here because of the high temperature of the flue gas, which is continuously over 250°C. The filters easily met all of the main requirements:

- Continuous operating temperature: 250°C.
- Peak temperature (up to 48 hrs): 350°C.
- Required dust emissions: <20mg/Nm$^3$.
- Maximum pressure drop: 20 mbar.

Ceramic candle filters could also be used in such a plant to filter the flue gas from the syngas treatment (Figure 8). This would offer optimal filtering performance without the typical heat waste due to the wet treatment system. In addition, the collected dust from the filter would not require any further treatment for drying.

## Conclusion

Candle elements present several interesting benefits for many applications in the oil and gas industry. Although CAPEX is higher, the OPEX savings are notable as ceramic candle filters require less energy, fewer cleaning cycles and reduced downtime. In addition, existing bag filter structures can, if desired, be retrofitted for ceramic elements. The capacity of ceramic elements to withstand continuous operating temperatures of 800°C and peak temperatures of up to 1000°C offer an opportunity to divest of cooling systems, thus increasing heat recovery and reducing overall system footprint.

Performance-wise, they are among the best on the market, offering emissions reductions of up to 1 mg/Nm$^3$ and easily filtering fine particulates, complying with the most stringent emission regulations. With pollutant legislation becoming stricter in many parts of the world, the fact that ceramic elements can be used with a wide variety of common reagents and sorbents to remove heavy metals, $NO_X$, acid gases and dioxins, makes them good contenders now and for the future. As with any technology, there are limitations and considerations. However, with the proper design guidance and trusted model testing, ceramic candle filters deserve consideration. HE