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Advances in the use of ceramic candle filters for hot gas clean-up removing dust particles with sticking properties

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Abstract

Various ceramic media for the cleaning of gases at high temperatures up to more than 1000 °C are already commercially available and semi-technical scale investigations as well as some pilot scale facilities have shown that in principle the separation of particles at high temperatures from gas streams may take place without major problems which, however, occur often in connection with the cleaning cycle of the dust loaded filter medium. Especially, low melting eutectic components in the dust particles may cause strong adhesion forces between the sampled particles in the filter cake and the filter medium resulting in a dust load that cannot be easily removed from the filter, at least not by means of pulse jet cleaning. The pressure drop will strongly increase and in many cases the filter cake is even irreversibly fixed to the filter elements.

The separation of comparably low melting dust particles has been studied at ambient and at higher temperatures including those at which sticking and melting of the particles occurred. The filter media were made of aluminium silicate fibres. To overcome problems with the removal of the dust load from the filter elements solid additives were used increasing the melting point of the particles and thus declining the adhesion forces between particles and the surface area of the filter elements. The additives applied offer besides the enhancement of the high temperature particulate separation process the advantage of removing simultaneously gaseous components like hydrogen chlorides from the stack gases of municipal incinerator flue gases. Another method to decrease adherence forces between filter and dust may be a coating of the filter medium.

KEYWORDS

Ceramic Filter, Pressure Drop, Pulse Jet Cleaning, Dust Characterisation, Solid Additives, High Temperature Filtration of Sticking Particles, Combined Gas and Particulate Separation, Gas Cleaning for Municipal Incinerators

1. Introduction

After a period of development of about two decades œramic filters for high temperature gas cleaning are already commercially available for several years. Like filter media used at temperatures below 250 °C, high temperature filters may achieve low concentrations of particulate matter in the cleaned gas, nearly unaffected by the dust content of the raw gas [1, 2, 3, 4]. The ceramic materials withstand corrosive gas components like sulphur oxides and hydrogen halides even at temperatures of more than 1000 °C. Also the filters can be used for the simultaneous removal of these gases by injection of dry sorbents which are separated together with the dust particles of the raw gas. Semi-technical scale investigations [5] have demonstrated that catalytically activated ceramic filters can be used as well for the removal of particulate matter as for the separation of gaseous components like nitrogen oxides, carbon monoxide and hydrocarbons. Besides that, high temperature gas cleaning offers energetic advantages and should decrease the de novo synthesis of toxic chlorinated organic compounds, e.g. polychlorinated dioxins and furanes. In spite of their benefits, ceramic filters for high temperature gas cleaning are still not used frequently in industrial applications. This situation is apparently caused by the fact that there is usually little knowledge about the influence of the properties of the particulate matter to the gas cleaning process.

Problems for high temperature gas cleaning processes will occur if the separated dust particles cannot be removed during the filter cleaning cycle from the surface of the filter medium. In principle, two main effects may affect the removal of the dust from the filter:

On one hand, the separated particles may not agglomerate to form a consistent dust cake which could be easily removed by pulse jet cleaning from the filter medium and settled into a dust bin, but would instead remain in the gas and finally return to the filter's surface. This would cause a steady increase of the amount of particles on the filter and thus of the pressure drop.

On the other hand, the particles which build the dust cake on the filter medium's surface may sinter or stick as fast together or may adhere on the filter medium not allowing a removal by pulse jet, back flow and possibly not even by rigorous use of mechanical forces.

Both effects are well-known from conventional filter processes operating up to about 250 °C. Below these temperatures, however, the cohesion forces and the agglomerating behaviour of the dust particles are strongly influenced by the presence

of the vapours of water and sulphuric acid which may condense, adsorb on the particles' surface or react chemically.

Whereas problems with non-agglomerating particles might be overcome by means of other more expensive cleaning techniques for the filter medium than pulse jet cleaning, the sticking or sintering of particles will usually make it necessary to use other gas cleaning processes, for instance wet scrubbers which may operate under these conditions. The change of the gas process as a whole, however, offers in general no alternative to filters for hot gas clean-up, because at present no other high temperature dust separator does work as successfully as barrier filters do.

As vapours of water and sulphuric acid are without importance at high temperatures, the conditions for dust sampling and cleaning of dust load filter media are far less controlled by properties of gaseous constituents than by those of the particulate matter. For instance, in most cases the maximum temperature of application will not be determined by the physical stability of the filter medium but by sticking, sintering or melting of the dust particles. Hence for a given field of application, it is necessary to investigate at first the properties of the dust particles and in some cases to look for possibilities to change them to accomplish a successful gas cleaning process.

Besides applications for novel coal conversion processes, hot gas clean-up may offer advantages in comparison to conventional gas cleaning for municipal incinerators. Therefore, examining the properties of dust particles in incineration processes with respect to their removal at high temperatures will be of great interest for future improvements in waste management.

2. Background

Dust particles in the flue gases from municipal incineration may vary in their physical and chemical properties over a wide scale, due to the heterogeneity of the wastes to be treated. The occurrence of many different chemical compounds in the ash will at least occasionally lead to eutectic mixtures causing sticking or melting of particles at temperatures which are comparatively low to that observed for ashes from the combustion of fossil fuels. It has to be taken into account that ash fusing points, as determined by standardised procedures, are not representative with respect to the behaviour of particles during the filter process. This is especially due to the fact that ash specimen for standard tests are prepared by combustion at tempera-

tures of more than 800 °C in a furnace where usually some of the low melting components evaporate. Besides that, sticking effects may already occur well below fusing points.

To investigate the properties of the particulate matter relevant to the cleaning of the dust load filter, it would be necessary to examine the dust behaviour under the conditions of the real flue gas of a municipal incinerator. This kind of investigation would obviously be not easy to be handled and at least cause high cost.

Alternatively, the behaviour of dust particles during the high temperature filter process might be studied under well-defined laboratory conditions. Such tests might match the conditions of the municipal incineration process quite well, even if they were carried out with small samples of the filter medium with a size of a few square centimetres, but only if the properties of the particulate matter to be separated were in good agreement with those occurring in the large scale process. On the other hand, small laboratory experiments will allow to change easily the properties as well of the dust as of the filter medium resulting in clues to overcome problems in connection with the high temperature gas cleaning. To optimise the dust properties additives come into consideration which might act as sorbents for gaseous constituents besides the changing of the sticking behaviour. Filter media are to be optimised to avoid clogging adhering of the dust cake and to achieve low pressure losses. The investigations presented in this paper are part of a European research project [6] financially supported by the European Community.

3. Experimental

3.1 Filter samples

For the filter experiments small cylindrical disks were used which were made of commercially available (BWF Offingen) filter media consisting of rigid fleeces of alumina silica fibres with diameters of about 5 µm. Table 1 surveys characteristic data of the material. Before use in high temperature experiments, the test samples underwent for at least two hours a thermal treatment at temperatures of 800 °C to destroy organic binders from the manufacturing. In some cases the specimen got special coatings to prevent clogging by adherent particles on the outer surface and in the interior porous structure of the fleece.

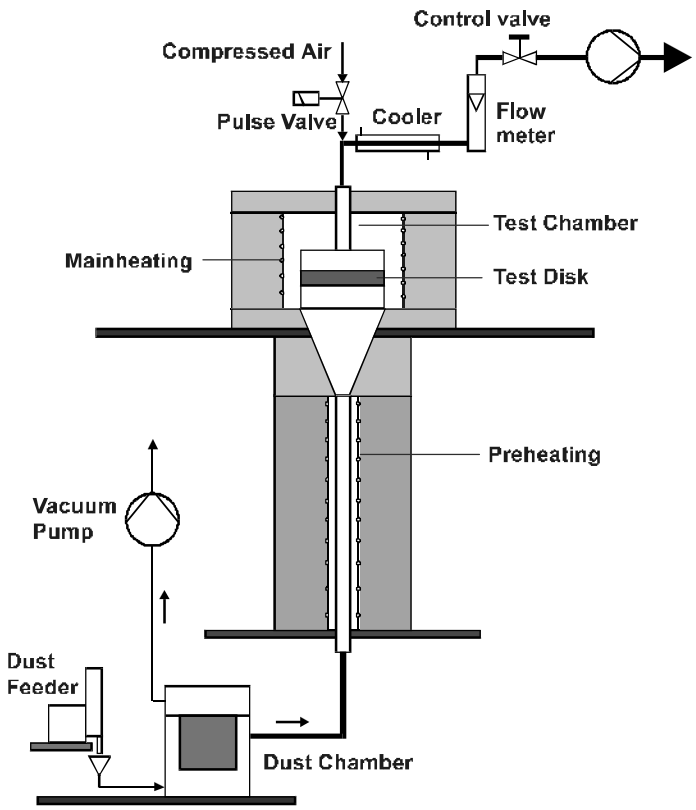
diameter of specimen / mm	45
thickness of specimen / mm	10 - 20

Table 1:
Technical data of the used ceramic filter media

diameter of the circular area passed by the gas flow / mm	32
mass per area / $g \cdot m^{-2}$	1800
mass of a filter sample / g	3.5
density / $g \cdot cm^{-3}$	0.18
air permeability / $l\ dm^{-2} \cdot min^{-1}$ at 200 Pa	20
porosity / %	95
open area per element / cm^{-2}	8

3. 2 Experimental apparatus

A flow sheet of the test rig for the examination of small ceramic fibre filter disks can be seen in figure 1.



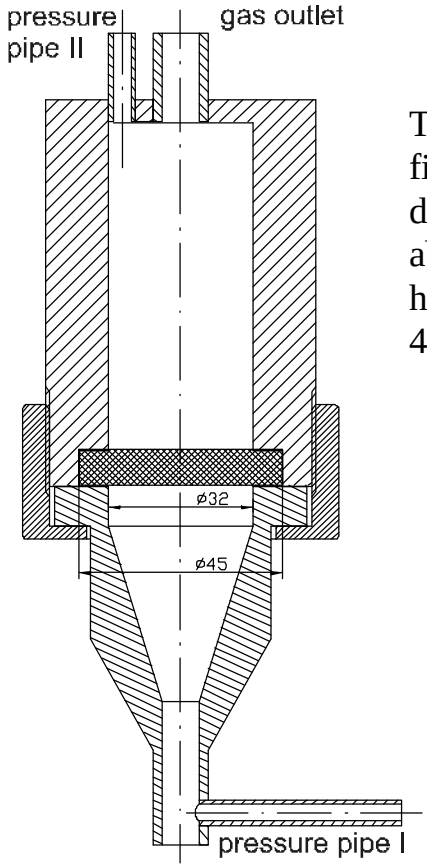
The filter disk is fixed in a test chamber, which is heated electrically. With the help of this main heating, filter temperatures up to 800 °C can be realised in the test chamber.

The filter gas stream is produced by an exhausting fan and controlled by a flow meter and a control valve. The dust loading of the filter gas stream takes place by a mechanical dust feeder and a dust chamber. In this configuration the dust is added to a main gas stream and dispersed in the dust chamber.

Fig. 1: Flow sheet of the test Rig

The main gas stream passes a pocket filter element for precleaning and is afterpurified in a vacuum cleaner. A small side stream is taken from the raw gas side of the dust chamber and let through the test disk in the test chamber. The dust loaded side stream passing to the test chamber is preheated by an electric radiator.

Before entering the flow meter the filter gas stream is cooled down to ambient temperature by a convection cooler. For filter cleaning a pulse valve is arranged at the top of the test chamber which is controlled by an electronic pulse generator. The pulse pressure can be adjusted by a reducing regulator between 0.5 and 9 bar. The temperatures of the preheating and the test chamber are measured by NiCr-Ni-thermocouples and controlled by electronic regulators. The pressure drop is measured by an electric transmitter and plotted on a line recorder. The construction of the disk test chamber is shown in figure 2.



The filter disks have a diameter of 45 mm, the open filter area amounts to 8 cm². The thickness of the disks can be varied up to 20 mm by using an adjustable screw clamp. The gas inlet and outlet tubes have a diameter of 8 mm, the pressure pipes of 4 mm.

Fig. 2:
Disk test chamber

3.3 Model dusts

As model dusts spherical A-glass particles (mean diameter: 4 µm, softening point 704 °C) and a standard test dust with varying additives are used with the compositions shown in table 2. As additives silica, limestone ($CaCO_3$) or anhydrite ($CaSO_4$) have been tested at present.

	A - Glass	**Standard dust**
SiO_2	72.5 %	58.3 %
Na_2O	13.7 %	11.0 %
$ZnCl_2$	-	10.0 %

Table 2:
Chemical composition of the model dusts

In order to improve the flowabilty of the standard dust a small amount of spherical silica particles (Aerosil 180, Degussa)

KCl	-	10.0 %
K_2O	0.1 %	-
CaO	9.8 %	7.8 %
MgO	3.3 %	2.6 %
Al_2O_3	0.4 %	0.3 %
FeO/Fe_2O_3	0.2 %	0.2 %

The particle size distribution of the standard dust is shown in figure 3.

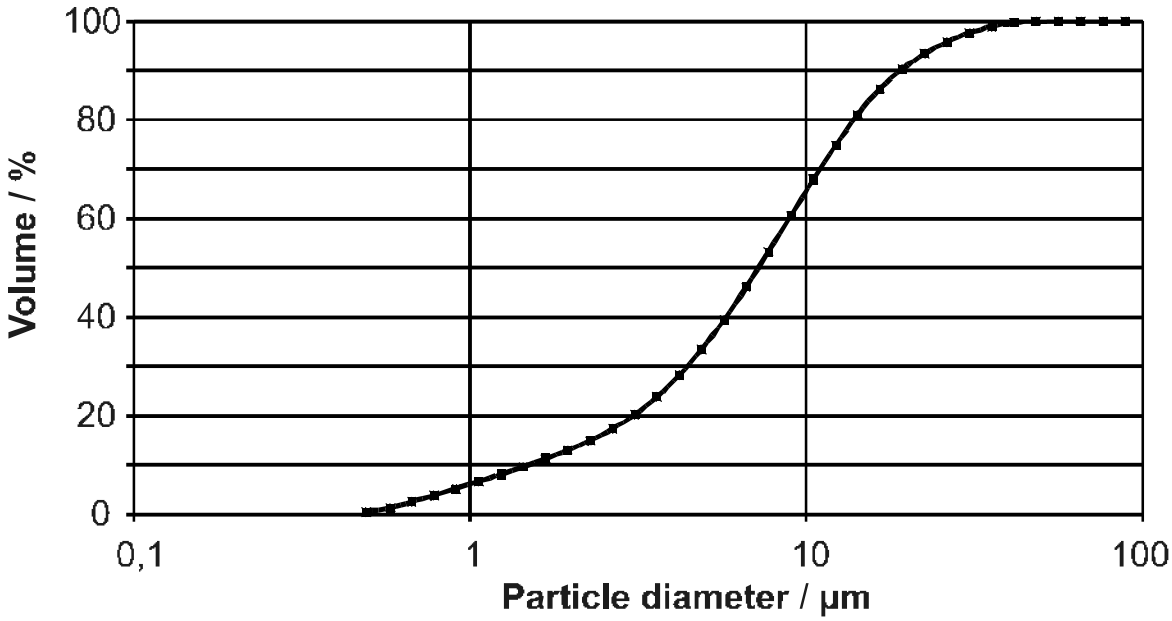
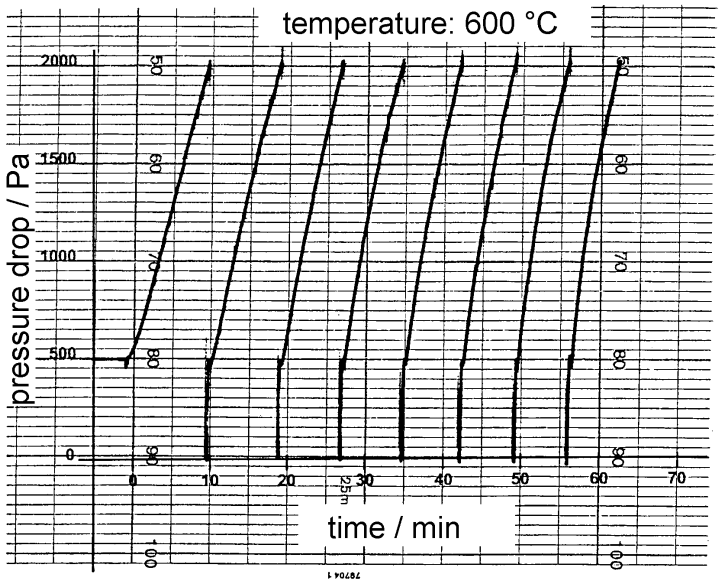


Fig. 3: Particle size distribution of the model dust

4. Results and discussion

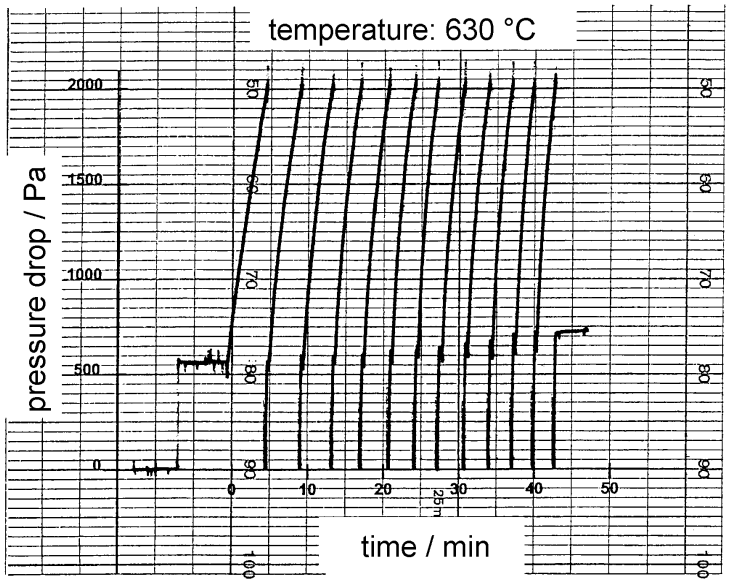
As already mentioned, sticking phenomena of dust particles occur frequently well below the softening point of the materials. Fig. 4 a and 4 b show pressure drops for the separation of A-glass dust (softening point 704 °C) over several cycles with pulse jet cleaning of the filter disk at 600 and 630 °C. Filter cleaning took place at maximum pressure losses of 2000 Pa. In order to obtain results during short test running periods extreme filter velocities of about 12.5 cm/s have been chosen for the test runs. At both temperatures the intervalls between the necessary cleaning pulses decrease with time, whereas at 630 °C a slow rising of the pressure loss for the cleaned filter can be observed.



At 600 °C the time intervals between 2 pulse cleanings decrease from about 10 min. at the start to about 6 min. for the 7. filter cycle, finished after about 56 min.

After cleaning at 600 °C the pressure drop of the starting point (about 500 Pa) is reached again.

Fig. 4a: Filter cleaning cycles at 600 °C



At 630 °C the time intervals between 2 pulse cleanings decrease from about 5 min. to about 2.5 min. for the 11. filter cycle, finished after about 40 min.

After cleaning at 600 °C the pressure drop of the starting point (about 550 Pa) is not reached again. The pressure loss increases up to about 700 Pa.

Fig. 4 b: Filter cleaning cycles at 630 °C

A detailed study of the sticking behaviour of dusts has shown, however, that it cannot be identified exactly by surveying pressure loss curves. In many cases, pressure loss curves above the sticking point show nearly the same behaviour as below the sticking point. For this reason, the behaviour of the dust has to be determined by macroscopic examination of the surface of the filter samples after pulse jet cleaning. A dust cake is called sticking if there is a distinct damage of the filter sample's surface or if parts of the dust layer are still remaining on the surface after pulse jet cleaning.

Figure 5 shows a filter sample after one filter cycle at 700 °C with succeeding pulse jet cleaning. There is a distinct damage of the surface and parts of the dust layer are still adhering to the surface. A filter sample after five filtration cycles at 600 °C with following pulse jet cleaning is shown in figure 5 b. The surface is undamaged and all the dust cake has been removed.

5 a 700 °C

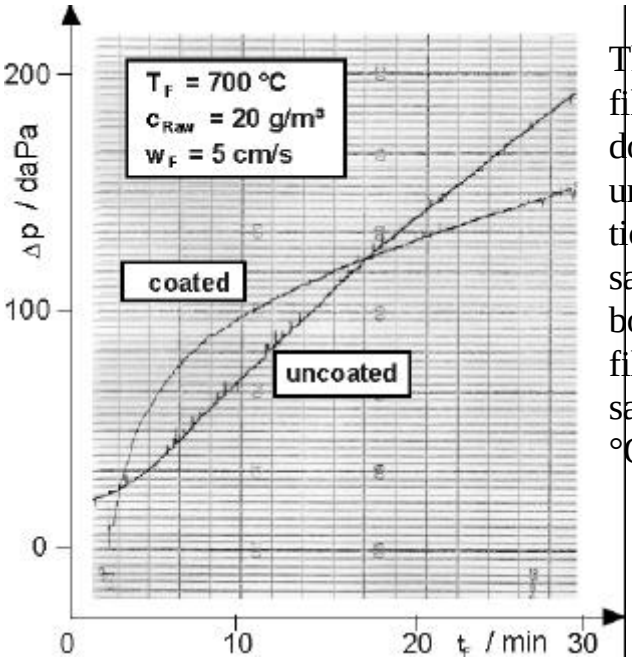
5 b 600 °C

Fig. 5: Filter surfaces after pulse jet cleaning

Further investigations showed that the sticking of the model dust, as described above, occurs between 650 °C and 700 °C. To guarantee a secure sticking of the model dust, the examinations are continued at the upper temperature of 700 °C.

There are two concepts to avoid sticking of dust or to shift the start of sticking to higher temperatures. On one hand it is tried to coat the filter surface with special substances in order to reduce the adhesive forces between filter and dust cake and on the other hand the dust properties may be influenced by conditioning the dust with additives.

Coating was carried out by the English project partners within the EU research project [6]. Figure 6 shows the different pressure drops of coated and uncoated filter samples at 700 °C. The dust cake on the coated samples could be removed even at 700 °C without damage of the filter surface.



The pressure loss curve of the coated filter sample can be interpreted by dominating surface filtration while the uncoated filter is infiltrated by dust particles. Hence for the uncoated filter samples, the filtration effect comprises both a surface filtration and a deep-bed filtration. The dust cake on the coated samples could be removed even at 700 °C without damage of the filter surface.

Fig 6: Pressure drop with and without coating

Investigations on conditioning of the up-flow dust stream are carried out with uncoated filter samples. Experiments with dusts, conditioned with $CaSO_4$ or $CaCO_3$, demonstrated that filters were cleaned easily above the sticking point of pure dust and without damage of the filter's surface.

Figure **7** shows as an example a scanning electron micrograph of dust conditioned with $CaSO_4$. The $CaSO_4$-component can be recognised by it's lamina structure. Dust that was conditioned with 30 mass % of $CaSO_4$ could be removed still at a Temperature of 750 °C.

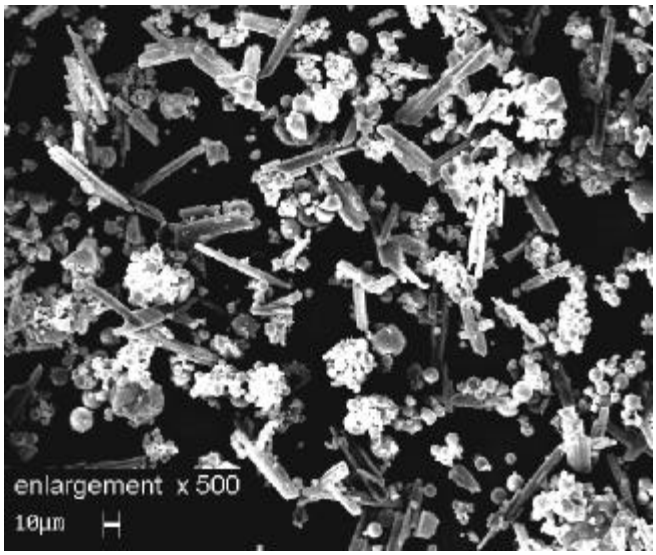


Fig. 7:
Electron micrograph of model dust conditioned with $CaSO_4$

Figure 8 finally shows two curves for pressure drops obtained as function of the filter velocity for standard dust and for standard dust conditioned with 30 mass % of $CaSO_4$.

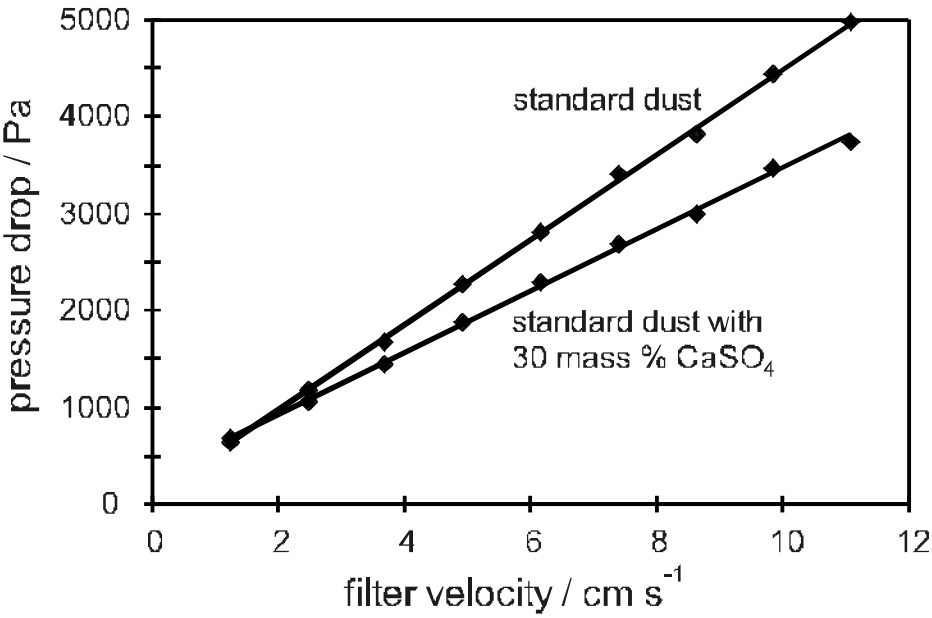


Fig. 8: Pressure drop at 700 °C for standard dust and conditioned dust

5. Conclusions

Clogging of filters, sticking of filter dusts as well as damaging of filter media may occur at temperatures below fusion or softening points. The problems in connection with these phenomena can, however, be avoided or at least diminished by improving the filter media with a surface coating and / or by applying additives like lime stone or anhydrite.

6. Acknowledgement

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7. References

[1] Weber E., Hübner K., Pape H.-G., Schulz R.: Gas cleaning under extreme conditions of temperature and pressure. Environmental International **vol. 6**, pp 349-360 (1981)

[2] Schmidt D., Schulz R., Bender J.: Long term tests with ceramic dust separators at gas temperatures between 800 °C and 1000 °C. 1st International Symposium „Gas Cleaning at High Temperatures“ Surrey 1986

[3] Weber E., Schulz R., Bender J.: Bau und Versuchsbetrieb einer Pilotanlage für die Hochtemperatur-Gasreinigung mit Filtrationsabscheidern. Final Report BMFT research project 03E 1259 A (1986)

[4] Schulz R.: Untersuchungen zur Staubabscheidung aus Gasen mit Filtrationsabscheidern bei hohen Temperaturen und Drücken. VDI Fortschrittberichte Reihe 3: Verfahrenstechnik, **Nr. 156,** VDI Verlag Düsseldorf 1988

[5] Hübner K., Pape A., Weber E.: Simultaneous Removal of Gaseous and Particulate Components by Catalytically Activated Ceramic Filters, 3rd International Symposium „Gas Cleaning at High Temperatures“ Karlsruhe 1996

[6] BRITE- EuRam III project funded by the European Community: Hot Gas Cleaning Using Advanced Ceramic Filter Technology for Municipal Waste Incinerators. Project No. BE 4065