Robert Mai
Forschungszentrum Karlsruhe GmbH,
Institut für Technische Chemie,
Bereich Thermische Abfallbehandlung,
Hermann-von-Helmholtz-Platz 1,
D-76344 Eggenstein-Leopoldshafen,
Germany
Phone: + 49 7247 / 82 - 3146
Fax: + 49 7247 / 82 - 6549
e-mail: robert.mai@itc-tab.fzk.de
(Primary Contact)

Hans Leibold
Forschungszentrum Karlsruhe GmbH,
Institut für Technische Chemie,
Bereich Thermische Abfallbehandlung,
Hermann-von-Helmholtz-Platz 1,
D-76344 Eggenstein-Leopoldshafen,
Germany
Phone: + 49 7247 / 82 - 3146
Fax: + 49 7247 / 82 - 6549
e-mail: hans.leibold@itc-tab.fzk.de

Helmut Seifert
Forschungszentrum Karlsruhe GmbH,
Institut für Technische Chemie,
Bereich Thermische Abfallbehandlung,
Hermann-von-Helmholtz-Platz 1,
D-76344 Eggenstein-Leopoldshafen,
Germany
Phone: + 49 7247 / 82 - 2655
Fax: + 49 7247 / 82 - 4373
e-mail: helmut.seifert@itc-tab.fzk.de

Steffen Heidenreich
Pall Schumacher GmbH,
Zur Flügelau 70,
D-74564 Crailsheim, Germany
Phone: + 49 7951 / 302 - 172
Fax: + 49 7951 / 302 - 280
e-mail: steffen.heidenreich@sut.com

Walter Haag
Pall Schumacher GmbH,
Zur Flügelau 70,
D-74564 Crailsheim, Germany
Phone: + 49 7951 / 302 - 151
Fax: + 49 7951 / 302 - 280
e-mail: walter.haag@sut.com

Operation Behavior of a Multi-Candle Filter with Coupled Pressure Pulse Recleaning during Normal Operation and in the Case of a Filter Candle Failure

Keywords: Multi-Candle Filter, CPP Recleaning System, Flow Distribution

Introduction – Pilot filter with CPP recleaning system

A pilot filter with the CPP recleaning system was installed and commissioned during the first half year of 2000 in “PYDRA”, the pyrolytic rotary tube facility of the Institute for Technical Chemistry, Research Center Karlsruhe (see **Figure 1**). The filter, with a rated throughput of 50 std.m^3/h, is equipped with two clusters of three filter candles each (DIA-SCHUMALITH® T 10-20, l = 1500 mm), and has been designed for a maximum operating temperature of 550 °C. After commissioning, the filter was run in the stand-alone mode, first without pyrolysis, to filter sticky inorganic dust of the type which can arise in waste incineration in the temperature range above 400 °C.

Figure 2 shows the schematic design of the CPP recleaning system for multi-candle systems as shown by the example of the pilot filter design. The filter candles are combined in clusters.

Clustering of the filter candles is achieved by the physical separation of the clean-gas region into several cells. Each filter candle is equipped with its individual safety filter. The recleaning valve separates the clean-gas cells from the feed tank for the recleaning gas. The recleaning gas may be any foreign gas (such as air, nitrogen, steam) or even cleaned product gas. The continued clean gas line contains a so-called hydraulic switch.

During filtration, the raw gas to be cleaned first passes through the filter candle, then through the safety filter, and, finally, through the hydraulic switch. The additional initial pressure drop as a result of the safety filter and the hydraulic switch, compared to the conventional jet pulse recleaning technique, is small.

For recleaning, the recleaning valve is opened and, as a consequence, the clean gas cell is connected with the feed tank. The recleaning gas stored in the feed tank is kept under a pressure only 0.05 – 0.1 MPa above systems pressure. The clean-gas cell, consequently, is briefly raised to a higher pressure level. In order to attain the necessary mass flow, the recleaning pipe and the recleaning valve are dimensioned sufficiently large. The flow characteristics of the hydraulic switch are such as to allow the flow to pass preferably through the safety filter into the filter candles where it removes the dust layer.

In case of a broken candle, raw gas enters the safety filter at a high face velocity because of the reduced drag at this point. In order to maintain a given dust level in the clean gas, the safety filter has a correspondingly high removal efficiency. Because of the high face velocity, the dust penetrates deep into the filter medium. The safety filter will be clogged up within a short span of time and thus cause this partial stream to stop. In order to prevent the dust from being discharged again in the following recleaning step, a filter element with depth filtration characteristics is used. Intensive dust removal would result in an increased loss of recleaning gas at this point and, consequently, reduce the recleaning intensity at the intact filter candles of the cluster involved. As a result of the blockage of the safety filter, the undamaged candles of the cluster of candles concerned are cleaned with undiminished intensity.

Filtration of sticky dust

To simulate the softening characteristics of flyash from the thermal treatment of waste and residues a special model dust has been developed. It consists of 80 wt.% of glass spheres (thermally stable up to 600 °C, softening temperature approx. 700 °C, MMD = 6.5 µm) and 20 wt.% of a salt mix of NaCl and $CaCl_2$ (molar ratio approx. 1 : 1). The salt mix exhibits a eutectic with a melting temperature of approx. 500°C. Rheometric measurements of these dusts document the fivefold increase in adhesive forces between 400 and 500 °C. The model dust was added to the raw gas flow by means of an external dosage device. The dust concentration in the raw gas was set to 10 g/std.m^3. The filter was operated in a time controlled recleaning mode. The time of a filtration cycle was adjusted to 60 minutes. Nitrogen at 400 °C was used as the recleaning gas, which reduces the thermal load and the hazard of condensation of gaseous components. The recleaning system was operated with a recleaning gas pressure of 0.1 MPa and a valve opening time of 250 ms.

Filtration test – Normal operation

By operating the filter system at 525 °C, a temperature above the melting temperature of the salt mix, a sticky dust with critical behavior related to recleaning was simulated. Part of the overall pressure drop curve of the filter system is shown in **Figure 3**. Stable filtration was achieved for more than 150 hours of operation. This result demonstrates that the recleaning intensities which can be achieved with the coupled pressure pulse system are so high that even sticky dust can be detached from the surface of the filter elements.

Filtration test – Simulation of a candle failure

In order to investigate the system in case of a candle failure one filter candle had been knocked off. Again the system was operated at a temperature of 525 °C and the model dust was used to simulate critical dust behavior. The volume flow rate was the same as in case of normal operation without candle failure. In **Figure 4** the start-up phase of the filter system is shown. The initial pressure drop of the system was higher than in case of normal operation. The reason might be a change in the dust cake properties because of the temperature decrease and increase for the simulation of the candle failure. The pressure drop curve indicates that the safety filter clogs fast and remains clogged because of its depth filtration characteristic. Again stable filtration was achieved for the critical model dust over nearly 500 hours. This demonstrates that the newly developed individual safety filters were successfully integrated into the filter system. From the pressure drop curve it can be very well distinguished when the cluster with the broken candle and when the cluster with the intact candles is recleaned. If the cluster with the broken candle is recleaned, a lower decrease of the pressure drop is attained as compared to the recleaning of the cluster with the intact candles.

Modeling of the system

Starting from the pressure drop characteristics of the single components, a simple model was developed to predict the pressure drop and the flow distribution in the filtration mode during normal operation and in case of a broken candle. The model allows the design and the optimization of the single components and of the overall system.

System performance – connection diagrams

In **Figure 5** and **Figure 6** the CPP system is depicted in so-called connection diagrams as used in electrical engineering. This illustrates the interconnection of the components and their serial (mass flow is constant) or parallel (pressure drop is constant) coupling. Under normal conditions (see **Figure 5**), dust load of individual candles of a certain cluster is taken identical. Thus the flow through these candles is identical, too. There is no flow distribution among the candles of a certain cluster. Because of the sequential regeneration mode the dust load of different clusters is not identical. Thus there is a flow distribution between the clusters which can be calculated numerically. During operation with a broken filter candle (see **Figure 6**), two cases must be considered. Directly after the breakage of a filter candle, its flow resistance can be neglected. The flow resistance of the safety filter increases with time. After clogging of the safety filter, the flow in this path is disrupted. Again the calculation of the flow distribution in the individual paths is performed numerically. Some results from the calculations (pressure drop and flow distribution) are shown in the following chapter. The operating conditions are comparable to those in the chapters *Filtration test – Normal operation* and *Filtration test – Simulation of a candle failure*. So the pressure drop behavior can be compared directly. The additional flow distribution gives an idea of how much the filtration behavior might be affected.

Calculations

Example #1 – Filtration test – Normal operation

Starting from the initial pressure drop with no dust the pressure drop increases with time (see **Figure 7**). The dust load for all candles rises in the same way. The normalized face velocity is 1 for all candles. When cluster #1 is recleaned for the first time pressure drop falls down to a value above the initial value. The flow through the candles of cluster #1 increases slightly (plus 3 %, see **Figure 8**) whilst the flow through the candles of cluster #2 decreases slightly (minus 3 %). During the following filtration cycle the normalized face velocities tend to equalize a little bit. When cluster #2 is recleaned the values change in a similar way. Flow distribution can be neglected when the dust resistance is low compared to the initial resistance of the system.

Example #2 – Filtration test – Simulation of a candle failure
In **Figure 9** the development of the flow distribution in the case of a candle failure is shown. Just after the breakage of a filter candle of cluster #1 the flow rate through this candle increases nearly by a factor of 3 for the given conditions. This knowledge is necessary for the layout of the safety filter. At the same time the flow through the remaining intact candles of cluster #1 decreases to 40 % and the flow through the candles of cluster #2 decreases to 80 %. With subsequent clogging of the safety filter the flow through the defect candle decreases exponentially. At the end of this clogging process the flow through the remaining candles is increased to 120% for cluster #1 and 110 % for cluster #2. The pressure drop behavior at the end of the clogging process is shown in **Figure 10**. It is similar to the measured. Again it can be distinguished when cluster #1 with the broken candle and when cluster #2 with the intact candles is recleaned. If cluster #1 with the broken candle is recleaned, a lower decrease of the pressure drop is attained as compared to the recleaning of cluster #2 with the intact candles.

Example #3 – Filtration test – Normal operation – high dust resistance
In the following the example #1 is discussed in the case of a 10 times higher dust cake resistance (e.g. higher dust concentration or longer cycle time). Again starting from the initial pressure drop with no dust the pressure drop increases with time (see **Figure 11**). The dust load for all candles rises in the same way. The normalized face velocity is 1 for all candles. When cluster #1 is recleaned for the first time pressure drop falls down to a value above the initial value. The flow through the candles of cluster #1 increases strong (plus 30 %) whilst the flow through the candles of cluster #2 decreases strong (minus 30 %). During the following filtration cycle the normalized face velocities tend to equalize. When cluster #2 is recleaned the values change in a similar way. Flow distribution cannot be neglected when the dust cake resistance is in the same order as the initial resistance of the system. Filtration behavior can be affected because there might be a shift from stable surface filtration to unstable depth filtration due to the increase of face velocity after regeneration.

Summary
A newly designed hot gas filter system has been presented. The filter system is based on ceramic filter candles with integrated individual safety filters and the coupled pressure pulse recleaning technique. Different filtration tests have been performed to check and to improve the single components of the system. The coupled pressure pulse recleaning technique has significant advantages compared to conventional jet pulse recleaning. High recleaning intensities are achieved with the CPP technique. Due to this fact stable filtration is obtained even for sticky dusts. Furthermore, as a result of the high recleaning intensity the residual pressure drop of the system is low. Hence, filtration cycle or filtration velocity can be increased which reduces operating or investment costs. The CPP recleaning technique requires a recleaning gas pressure which exceeds the system pressure by only 0.05 to 0.1 MPa. This also reduces investment and operating costs. Moreover, the CPP recleaning method offers the possibility to integrate a safety filter for each filter candle. The safety filters developed have low pressure drop and clog fast. A stable and safe operation of the newly designed filter

system is given in case of candle failures. This has been demonstrated for the filtration of a sticky model dust. An unscheduled cost-intensive shut down of ceramic filter systems caused by candle failures is no longer a problem using this promising new filter system.

A simple mathematical model concerning flow distribution among different candles in a candle cluster and among different candle clusters in the filter vessel allows the calculation of the pressure drop behavior. A good agreement between the calculated and the measured values was achieved. The model shows that there is a big influence of the dust cake thickness just before recleaning on filtration behavior which should be taken into account when designing a filter unit. Filtration behavior can be affected because there might be a shift from stable surface filtration to unstable depth filtration due to the increase of face velocity after regeneration.

References

R. Mai, D. Kreft, H. Leibold, H. Seifert: “Coupled Pressure Pulse (CPP) Recleaning of Ceramic Filter Candles – Components and System Performance“. 5th European Conference on Industrial Furnaces and Boilers (INFUB 2000), April 11-14, 2000, Porto, Portugal, preprints

R. Mai, B. Zimmerlin, H. Leibold, H. Seifert: “High Temperature Dust Filtration in a Waste Pyrolysis Process“. International Conference on Incineration and Thermal Treatment Technologies (2000 IT3), May 8-12, 2000, Portland, Oregon, USA, proceedings 9/5

S. Heidenreich, W. Haag, A. Walch, R. Mai, D. Kreft, H. Leibold: “A Newly Designed Ceramic Hot Gas Filter System – Filtration Tests with Waste Pyrolysis Gases”. PARTEC 2001, March 27-29, 2001, Nürnberg, Germany

B. Zimmerlin, H. Leibold, H. Seifert: “Development of a model dust for the simulation of fine and sticky dust”. PARTEC 2001, March 27-29, 2001, Nürnberg, Germany

R. Mai, H. Leibold, H. Seifert, W. Haag, S. Heidenreich, A. Walch: “Comparison of coupled pressure pulse (CCP) recleaning and jet pulse recleaning during the filtration of sticky dust”. FILTECH EUROPA 2001: Europe's Market Place for Filtration and Separation Technology; International Conference and Exhibition, Düsseldorf, Germany, October 16-18, 2001, Proceedings Volume II, pp. 605-611

Figure 1: Pilot filter as a part of the pyrolysis plant “PYDRA” at the Research Center of Karlsruhe.

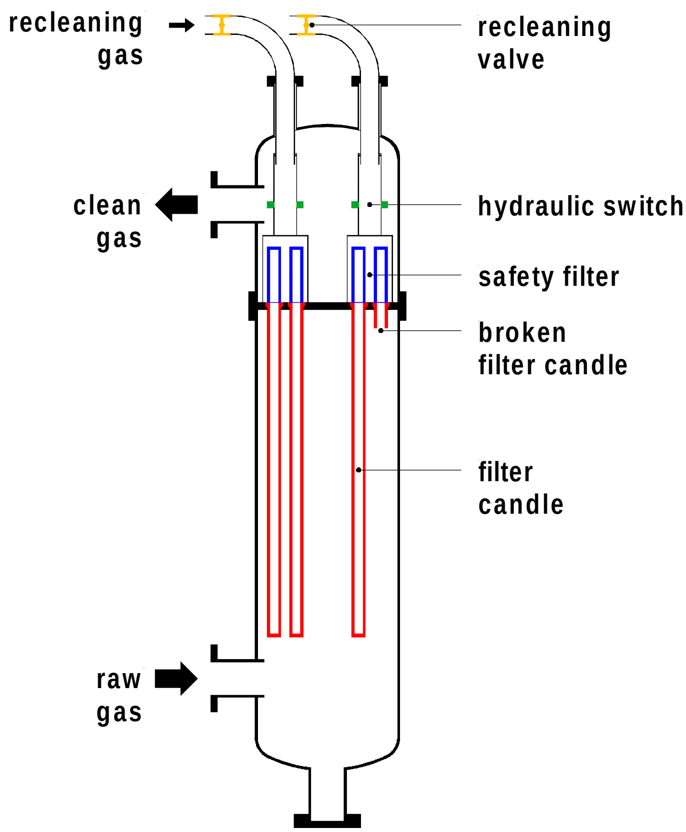

Figure 2: Schematic setup of the pilot filter with the Coupled Pressure Pulse (CPP) Recleaning System and integrated safety filter.

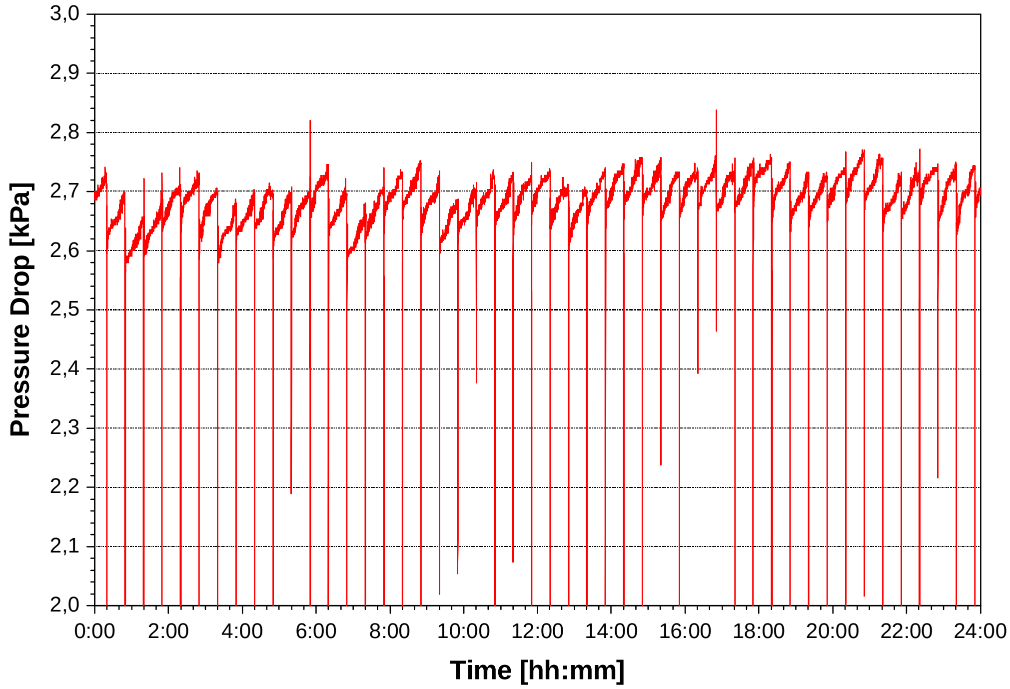

Figure 3: Normal operation. Pressure drop of the filter system operated with model dust at 525 °C, face velocity 85 m/h, recleaning gas pressure 0.1 MPa.

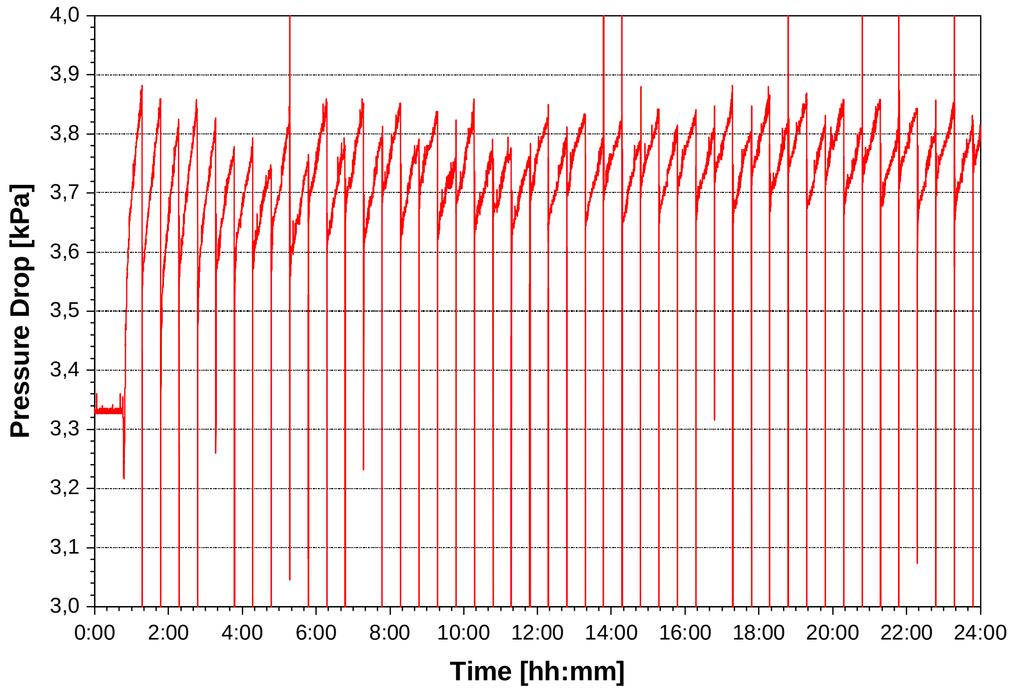

Figure 4: Simulated candle failure. Pressure drop of the filter system operated with model dust at 525 °C, face velocity 85 m/h, recleaning gas pressure 0.1 MPa.

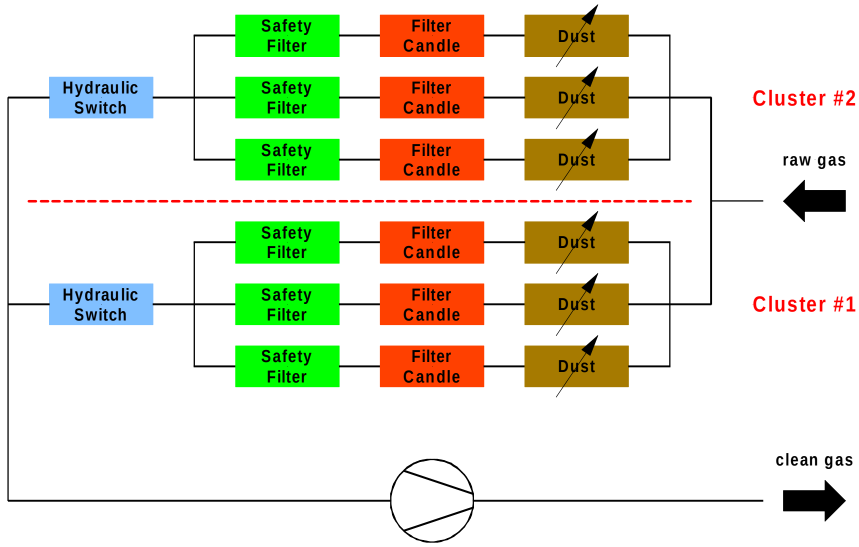

Figure 5: Filtration mode - normal operation

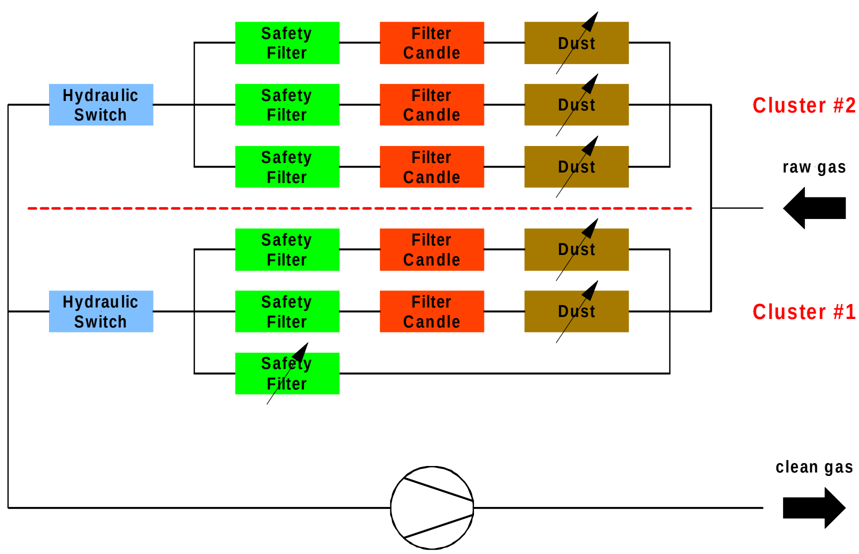

Figure 6: Filtration mode - operation with a broken candle

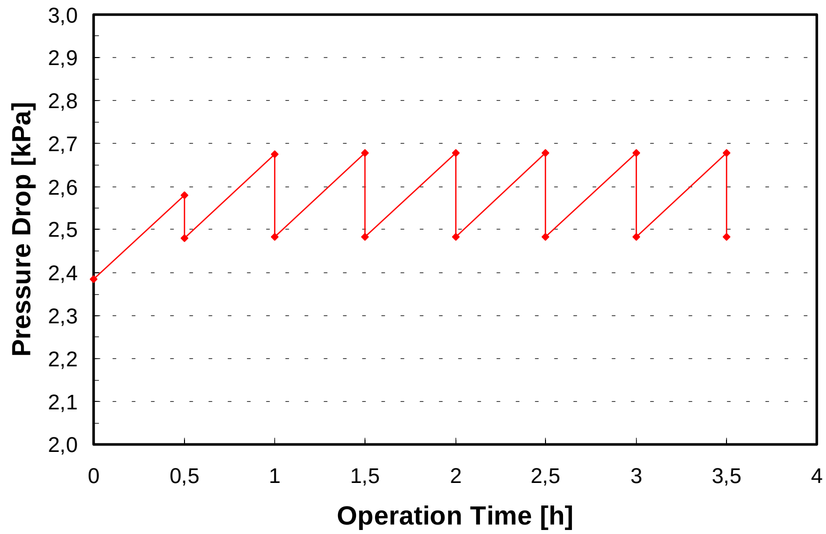

Figure 7: Example #1 – normal operation. Pressure drop (comparably with Figure 3) of the filter system operated at 525 °C, face velocity 85 m/h.

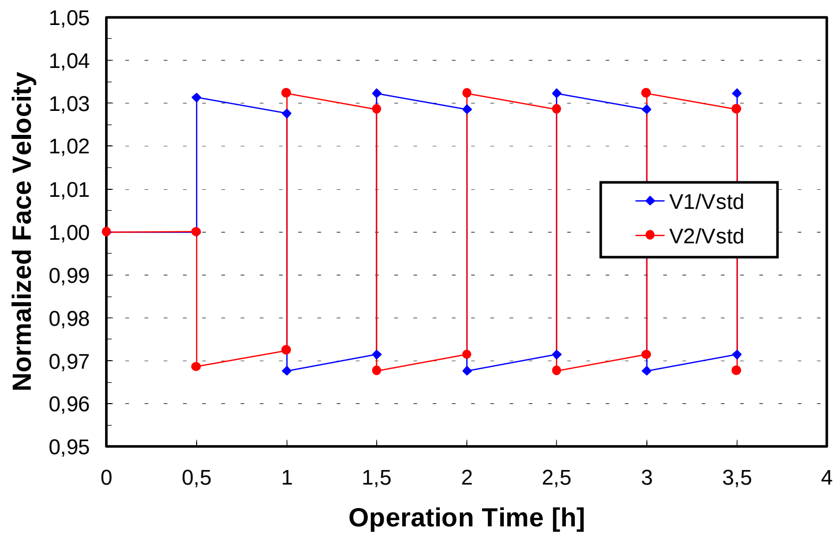

Figure 8: Example #1 – normal operation. Flow distribution of the filter system operated at 525 °C, face velocity 85 m/h.

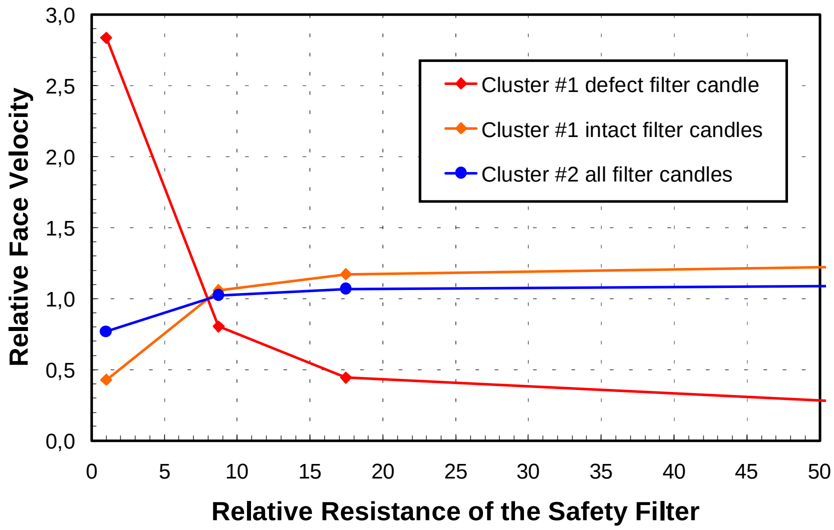

Figure 9: Example #2 – simulated candle failure. Development of the flow distribution with increasing resistance of the safety filter due to clogging.

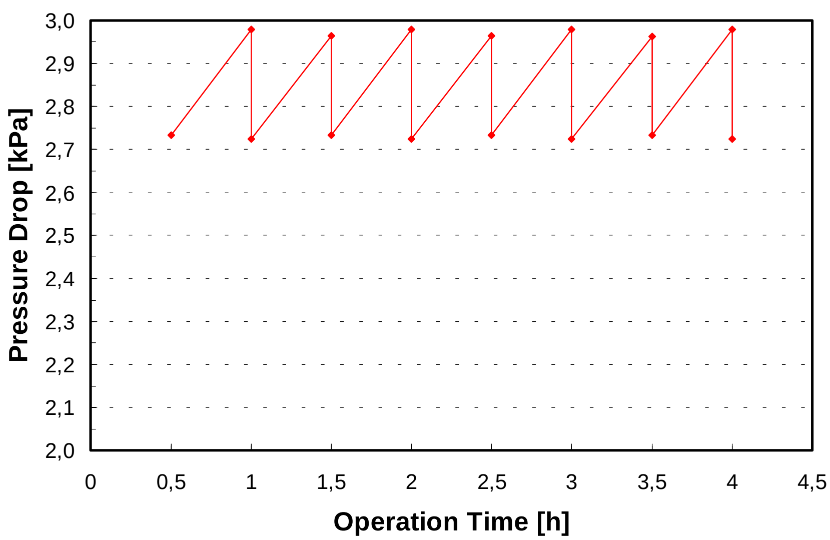

Figure 10: Example #2 – simulated candle failure. Pressure drop of the filter system operated at 525 °C, face velocity 85 m/h – comparably with Figure 4.

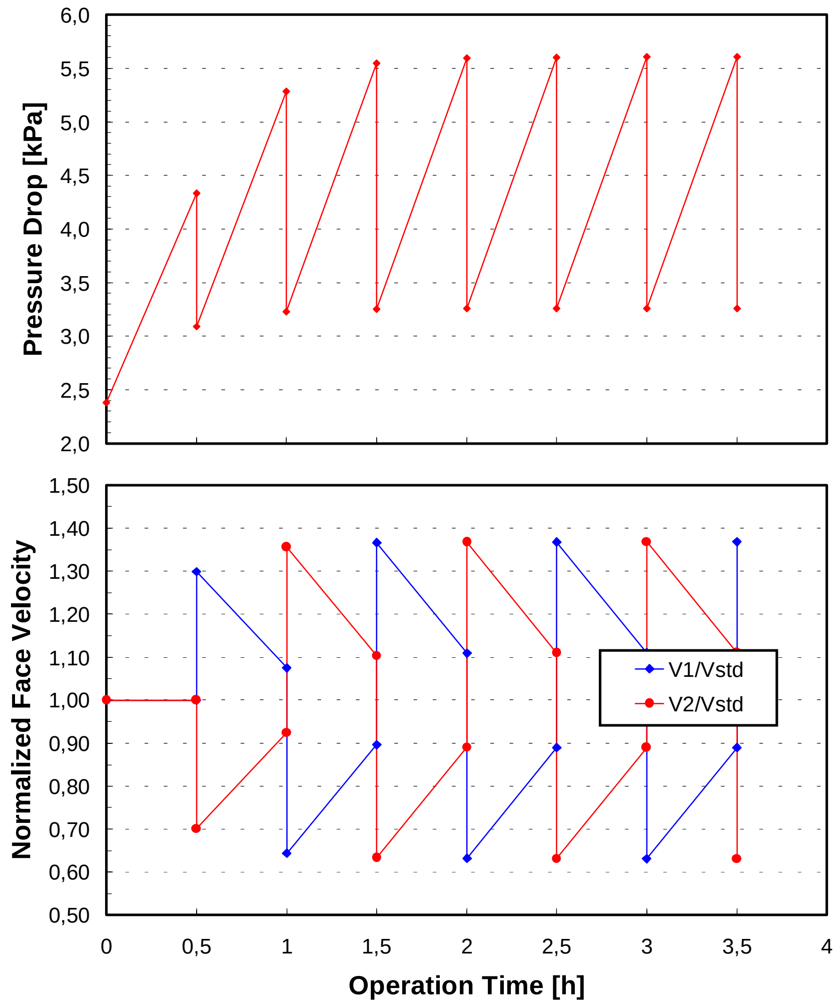

Figure 11: Example #3 – normal operation. Pressure drop and flow distribution of the filter system operated at 525 °C, face velocity 85 m/h – dust cake resistance 10 times higher than in **Figure 7** and **Figure 8**.