Light Metals 1988

ADDENDUM

Papers presented at the 116th TMS Annual Meeting,
Denver, Colorado, February 24-26, 1982
The filter cake is removed from the filter cloth by static pressure and/or inertia forces. The main influencing parameters for the discharge due to static pressure alone are the permeability of the filter cake and the mass flow of compressed air per unit filter surface area.

The decisive factors for the cake removal by inertia forces alone are the mass flow per unit cell area and the volume increase of the cell as a function of the cell pressure. Discharge improvements can be accomplished by larger pressure vessels, pressure lines with a larger diameter, control valve geometries with large intersection zones and fast overlap; with filter cells of small cell angle and interior volume, and with filter cloths with a high modulus of elasticity.

**INTRODUCTION**

In order to remove the cake formed during filtration, compressed air from a pressure vessel is fed into the filter cell over a compressed air line (see Fig. 1). As a result of this, a pressure rise (which should be as fast as possible) occurs inside the filter cell, accelerating the filter cloth and its adhering cake outward. When the cloth has been inflated by a few millimeters, it reaches its full outward expansion and decelerates again, its slow movement leading to an even faster pressure increase within the cell. From the acceleration and increased internal cell pressure, both inertia and pressure forces act upon the cake, causing it to be detached from the substrate on which the cake is located, where the adhesion forces are overcome. This process is known as reverse-flow cake discharge.

As soon as the pressure within the filter cell exceeds that of its surrounding, air leaves through the cake into the atmosphere. This air loss impedes the pressure rise and hence the cake discharge. The quantity of air loss depends upon the permeability of the filter cloth and cake, its level of saturation with liquid and the pressure difference. Provided that the mass flow through the filter cake is smaller than that which can flow through the filtrate piping system into the cell, the pressure within the cell will increase.

In Fig. 2, the equilibrium pressure resulting from the inward and outward flow of gas quantity is determined. In this graph, the vessel pressure (left coordinate) is plotted as a function of the mass flow through the filtrate piping, i.e., mass flow entering the cell (these are the calculated points which are close together). The different mass flow were accomplished with the aid of various aperture-stops built into the air line. The corresponding aperture-stops diameters are given in the key at the bottom right of the figure. Additionally, the cell pressure fully due to an overpressure within the cell, is possible.

The prerequisites for this is that the cloth’s pressure loss is negligibly small, as this increases just the cloth and not the cake. In the case of a correctly chosen material, its pressure loss is indeed considerably smaller than that of the cake. Should, however, the cloth held during operation, then its pressure loss may increase substantially and hence impair the cake discharge.

In Fig. 1, Schematic of a disc filter

1. Discharge zone  
2. Dewetting zone  
3. Cake formation zone  
4. Control head and disc  
5. Vacuum connection

The pressure loss is due to the airflow through the cloth and cake. The cake is located on the substrate, where the adhesion forces are overcome. This process is known as reverse-flow cake discharge.
Experiment on a pilot filter to determine the pressure necessary to remove the cake by means of static overpressure (right coordinate). The mass flow through the cake (escaping mass flow) was measured experimentally for a variety of cell angles (15° – 35°). The results of these measurements for a flotation coal and with different filter areas are also illustrated in Fig. 2, the accompanying cell angle being given at each curve.

In order to determine the overpressure necessary to remove the cake, the adhesion force of the flotation coal was measured at the filter cloth (value at the side of the right coordinate). In the case of the flotation coal used for the investigations, this was 900 N/m². If the pressure within the filter cell attains this value, then the cake can be removed from it by means of the overpressure alone.

For this purpose, the mass flow through the filter cake was determined as a dependent function of the cell permeability for the 22.5° cell, in that the adhesion force was drawn over the left of the 22.5° curve. This mass flow must exist at the filter cell.

The vessel pressure necessary in order to accomplish this, depends upon the filter cell piping. In Fig. 2, this pressure has been determined for a 6.2 mm aperture-stop. Here, the mass flow is drawn perpendicularly up to the curve for the 6.2 mm aperture-stop, and the accompanying vessel pressure read from the left coordinate.

The necessary vessel pressure for the experimental 10° cell is determined analogously (broken line), whereas the horizontally running upper line portion has been lowered somewhat for the purpose of clarity, as this otherwise coincides with the line drawn for the 22.5° cell.

In order to be able to compare the calculated and measured necessary vessel pressures, the experimentally determined values have been given at the left coordinate for the 22.5° and the 10° cells. The measured values are given by the histogram at the left of the diagram, the stated pressures being those at the start of cake discharge.

An enlargement of the pipe diameter leads to a considerable increase in the pressure rise, at the cost of a higher air consumption, as the mass flow also increases. A reduction of the cell size leads to...
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<th>$V_K$</th>
<th>$d_K$</th>
<th>$T_K$</th>
<th>$P_{K,0}$</th>
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<td>Liter</td>
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<td>°K</td>
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<td>Liter</td>
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Table 1: Numerical values of the filter dimensioning for the examples given by figs. 2 and 3

![Graph 1](image1.png)

![Graph 2](image2.png)

Fig. 3 and 4:
Gas mass flow through the disc filter and pressure trend within the filter cell as a function of time, assuming that frictional losses are negligible.

- Pilot filter
- disadvantageous design
- large vessel
- wide pipe diameter
- small filter cell volume
- advantageous design
- filter cell fitted up with atmosphere before blow back
a slower rate rise and a reduction of air consumption. This proves that the cell volume should be as small as possible as long as a certain size is no prerequisite (e.g. for other purposes such as filtrate storage during the cake formation phase).

In order to save space and compressed air when pressurizing the filter cell, this is allowed to fill to atmospheric pressure before applying the blowback. The filter cloth movement then immediately begins at the start of the pressurization phase and thus at a low air flow rate. This means that smaller kernels force act upon the filter cloth and therefore the prevention of the cell is not of advantage, but often quite the opposite. One exception of this, however, is given by the case where the cake discharge occurs by means of a "quasi-static dislodgement", i.e., due to a static internal cell overpressure alone.

**INFLUENCES OF THE PIPING LOSSES OF INDUSTRIAL FILTERS ON THE AIR FLOW**

The piping losses of industrial disc filters differ significantly from one another due to individual constructive features. The length of piping generally lies between 300 and 6000 mm, their diameter between 30 and 80 mm. Thus, with a pipe friction number of \( f = 0.022 \) (for approx. 10\(^{3}\)), the piping losses are between 0.14 and 4.4 as can be seen in Table 2. Should the pipes be of slightly rusty cast-iron, then these values can easily be several times larger.

In addition to this, the losses due to 90\(^\circ\) manifolds are also relevant. These losses, depending upon the number of such manifolds built into the system and their diameter (given by Table 3), are between 0.36 and 2.34.

**Table 2:** Piping loss coefficients of industrial disc filters

<table>
<thead>
<tr>
<th>Pipe diameter (mm)</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
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<td>2.64</td>
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**Table 3:** Loss coefficients of industrial disc filter piping

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<tr>
<th>Manifold as per DIN 2465</th>
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**Fig. 5:** Function of the mass flow to the piping diameter for various coefficients of resistance

In order to illustrate the influence of the piping losses, the mass flow through pipes as function of the pipe diameters is given in Fig. 5 for a variety of resistance coefficients, at a pressure difference of 0.5 bar. The ratio of frictionless
to friction impeded mass flow is a measure of the piping's quality.

**Comparison of different intersection designs**

In the control valve:

Considering slowly rotating filters with rapidly moving valves, a substantial quantity of compressed air can escape through the cake into the atmosphere before the whole pipe cross-section is exposed to the flow at the control valve. In the case of rapidly rotating filters (disc filters were operated at speeds of up to 6 rev/min within the scope of this and other projects), the opening time is less than 1/3 sec so that, for ease, one must take care that within the initial period, an adequate compressed air quantity can flow into the filter cell.

The compressed air line is under pressure up to the control valve. The passage of the filter pipe system is opened to the compressed air in a manner depending upon the rotary speed of the filter and the control geometry. The air flows through the control valve and the filtrate pipe up to the filter cell. The mass flow of the air depends upon the geometry of the intersection area.

In the simplest case, this is executed by intersecting the filtrate feed pipe with the compressed air line. Providing such pipes are of circular cross-section, the area of intersection corresponds to that of two overlapping circles (Fig. 6a). An improvement of the cake discharge can be accomplished by means of constructive improvements to the inlet valve geometry. For example, the gradient of the intersection area of the rectangular valve (as shown in Fig. 6b) can be observed to be significantly steeper. In order to improve older filters, constructed with a circular pipe intersection, the control zone may be subsequently modified to crescents, as shown in Fig. 6c.

A comparison of the illustrated control geometries shows that in the instance of a circular/circular intersection, the opening sequence occurs progressively. For the slout and crescent forms, however, the intersection occurs linearly with a rapid opening. In fact, the opening functions being approximately the same for both. Therefore, modern disc filter control valves are designed with much slout. Older disc filters having a circular/circular overlap geometry may be modified to a crescent form, thus enabling almost the same opening characteristics to be obtained.

**Influence of the filter cell upon the pressure rise**

The pressure rise gradient as a function of the cells' bulge volume is a critical parameter for the cake discharge. This depends on the compressed air quantity which must be introduced into the cell in order to maintain a certain cell pressure. The pressure within the filter cell as a function of the cells' bulge volume is given in Fig. 7.

The curves of the necessary vessel pressure (bar) required to completely release the cake from the cloth of the disc filter apparatus vary as a parameter of the filter cell angle.

It is clearly evident that with increasing cell angle, the compressed air quantity necessary to achieve a certain cell pressure decreases. Large cell angles thus require longer control valve opening times for identical piping and hence slower rotation filter speeds and large compressed air quantities.

![Fig. 6a: Different control valve geometries](image)

![Fig. 6b: Circular/circular intersection](image)

![Fig. 6c: Crescent intersection](image)
Fig. 2: Results of the calculation of the equilibrium pressure as a function of the filter cloth bulge volume for different filter cell angles.

The reason for this behavior is that the perpendicular forces acting upon the cloth can only be withstand when the cloth bulges outward. The radius of the bulge decreases, however, with increasing span lengths.

In Fig. 3, the pressure within the filter cell is plotted as a function of the filter cloth's bulge volume for cloth modules of elasticity of $10^3$, $5 \times 10^3$, and $10^5$ N/m². The filter cloths used for the adhesion force measurements being within this region. The force generated by the tensioning apparatus is related to the breadth of the cloth stretched over it. The calculations for Fig. 3 were conducted for a 20 mm filter cell of 1.8 m length with an unstretched cloth. The figure shows that the module of elasticity can largely contribute to the rapid cell pressure increase. Should the compressed air supply not be adequate, the choice of a filter cloth with a large module of elasticity can lead to an improved cake discharge.

The filter cloth may be pre-stressed over either its length or breadth, or both can be left loose. Fig. 4 shows an example of a pre-stressing over the cloth's breadth. Here, the filter cloth angle is 15 to 25 larger or smaller than that of the filter cell respectively. The module of elasticity of the cloth is $5 \times 10^5$ N/m² and the length of the filter cell is 1.8 m. The cell pressure is again plotted as a function of the cloth's bulge volume. The middle curve represents the instance where the cloth simply lay flat upon the cell without any pre-stress. Upon stretching the cloth by just approx. 15%, a significant increase of pressure rise results, which can be of advantage in a system with an undisturbed compressed air supply. However, the cloth with an angle of 25% larger than that of the cell may also be advantageous. It offers a large region where the pressure hardly increases. Here, a high filter cloth velocity can be attained, whereby sharp deflections with sudden pressure rises create rapid filter cloth accelerations.

Fig. 5: Mathematically determined influence of the module of elasticity upon the cell pressure trend, as a function of the filter cloth's bulge volume.

Fig. 6: Function of the calculated pressure in the filter cell over the bulge volume for different filter cloth breadth pre-stresses.

Here, however, a large air consumption over a relatively short period must be at disposal, which cannot be accomplished by slowly rotating industrial equipment equipped with the normal control valve. This is only possible by means of a largely displaced, rapidly opening solenoid valve (a so-called snap-blow valve).
The pre-tensioning over the cloth's length is portrayed in Fig. 10. It can be seen that the cloth stress over its length is not all that important. A significant effect is only to be accomplished with unrealistically high tensions. In order to gain better results, the cloth must be subdivided into a number of segments over its breadth. Not only is the tension over the cloth's length, but also that over its breadth, limited by the plastic deformation of the cloth material.

From data supplied by filter cloth manufacturers, an elongation of 2% should not be exceeded. The pressure within the filter cell over the bulge volume increases much slower when the length of the cell is extended (Fig. 11). This is not caused by the elongation of the fibres over the cloth's length, as the strain is largely carried by the cross-fibres as shown in Fig. 10.

The cause lies in the cell area enlargement and the elongation of the cross-fibres at the upper cell section.

Fig. 12 shows finally, the experimental results for cell angles of 33°, 22.5° and 10°. The abscissa represents the pressure in the compressed air reservoir and the ordinate, the mass ratio of discharge filter cake to filter cake deposition. The 33° cell only begins to release the cake at 3.3 bar and will not throw off the entire cake below 5 bar. A reduction of the cell angle to 22.5° leads to a considerably lower discharge pressure. The 22.5° cell begins to discharge at a pressure of 0.6 bar and throws the filter cake completely off at 1.3 bar.

The thickness of two filter cells was also varied. The 22.5° cell (narrow) was constructed half as thick as normal, and the 10° cell (conical) was made half as thick and with a conical form. Therefore, the 22.5° cell (narrow) and the 10° cell both comprised the same volume, but different cell angles. The different angles are made apparent by the gas losses through

**Fig. 10**: Functions of the calculated pressure in the filter cell over the bulge volume for different filter cloth length pre-stresses

**Fig. 11**: Pressure in the filter cell as a function of the bulge volume for different filter cell lengths

**Fig. 12**: Comparison of different filter cells

- 33° cell
- 22.5° cell
- 10° cell
- 22.5° cell (narrow)
- 10° cell (conical)

The filter cake. This effects the necessary pressure at the beginning of the cake discharge, which increases from 0.5 to 0.8 bar. The pressure necessary to fully remove the cake from the filter cell in approx. 1.3 bar, whereby the inertia forces necessary to remove a 3 mm thick cake depends upon the cell volume. Here, the cell volume is the same in both instances.

The best cake discharge results were obtained by the conical 10° filter cell, as this allowed an even more uniform pressure rise over the cell's length, and because of the smaller cell volume, a faster pressure increase.
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