PRESSURE DROP THROUGH INSIDE COLLECTORS (SHAKER OR REVERSE-GAS CLEANING)

The relevant equation for pressure drop, ΔP, is:

$$\Delta P = K_1 V + K_2 V W \quad (1)$$

The first term on the right side of Eq (1) is the pressure drop through the fabric, whereas the second term is the pressure drop through the dust deposit. Here, K_1 is the resistance of the fabric, K_2 is the specific resistance of the dust deposit, V is filtration velocity, and W is the areal density of the dust deposit measured in units of mass per unit area.

For pressure drop through the dust deposit alone,

$$K_2 = \frac{\Delta P}{V\,W} = \frac{\Sigma\,(\text{Force / Area})}{V\,\Sigma\,(\text{Mass / Area})} \quad (2)$$

Note that "Area" cancels out of the equation. If the number of particles in the dust deposit is "n" and all of them have diameter "d", then Stokes's Law can be used to determine the drag force on each particle. This calculation requires the assumption that all particles are isolated from each other, a situation that is unrealistic within a dust deposit.

$$K_2 = \frac{n\,\dfrac{3\pi\mu d V}{C_C}}{V\;n\,\dfrac{\pi d^3}{6}\,\rho_p} = \frac{18\,\mu}{d^2\,\rho_p\,C_C} = \frac{1}{\tau} \quad (3)$$

K_2 must be modified to account for the crowding of the streamlines as gas flows around the particles. The revised equation is:

$$K_2 = R\,(1/\tau) \quad (4)$$

Where R is a correction factor greater than unity.

Equations for R are presented by Kozeny-Carman and by Rudnick-Happel. The Kozeny-Carman equation is:

$$R = \frac{2\,k\,\alpha}{(1-\alpha)^3} \quad (5)$$

where α is the solidity of the dust deposit and k is a constant. The value of k = 4.8 for spheres and k=5 for "irregular" particles.

The Rudnick-Happel equation is:

$$R = \frac{3 + 2\,\alpha^{5/3}}{3 - 4.5\,\alpha^{1/3} + 4.5\,\alpha^{5/3} - 3\,\alpha^2}\ . \quad (6)$$

Unfortunately, both the Kozeny Carman and the Rudnick-Happel equations depend on knowledge of the solidity of the dust deposit, a term that is difficult to know accurately. As a result, K_2 values cannot readily be calculated from theory. Tabulated values of K_2 can be found in the literature, but the numbers listed depend strongly on the particular characteristics of the dust, fabric, and operating conditions present at the time of the test.

PRESSURE DROP THROUGH OUTSIDE COLLECTORS (PULSE-JET CLEANED FILTERS)

The most important equations are given below:

$$\Delta P = \frac{P_s + K_1 V - \sqrt{(P_s - K_1 V)^2 - 4 w_o V K_2 / K_3}}{2} + K_v V^2 \qquad (7)$$

where:

$$P_s\ (\mathrm{Pa}) = 164 [P\,(\mathrm{kPa})]^{0.6} \qquad (8)$$

and

$$w_o = C_i\, V\, t\ . \qquad (9)$$

Here P_s, measured in Pa, is the pressure generated inside a bag by a pulse that has pressure P measured in kPa, C_i is inlet dust concentration, and t is the time between cleaning pulses to any bag. K_v is a constant for flow through a venturi, and has a value of about 60,000 Pa s^2m^{-2}. The values of constants K_1 and K_2/K_3 depend on the properties of the fabric surface as in Table 1.

Table 1. K_1 and K_2/K_3 from Regression Analysis

Fabric Surface Treatment	Clean Fabric Resistance, K_1, Pa s m^{-1}	K_2/K_3 Pa s^{-1}
Untreated Felt	712	0.674×10^{10}
Singed Felt	613	0.444×10^{10}
PTFE Laminated Felt	1530	1.880×10^{10}

Perhaps the most effective way to use these relationships is to solve the pressure drop equation for the value of K_2/K_3 for a given application. Then the effect on pressure drop of changing operating conditions, such as changing t or V, can be determined. Rearranging the pressure drop equation gives

$$K_2/K_3 = \frac{(P_s - K_1 V)^2 - [P_s + K_1 V - 2\left(\Delta P - K_v V^2\right)]^2}{4 w_o V}\ . \qquad (10)$$

References:

Leith, David and Michael J. Ellenbecker, "Theory for Pressure Drop in a Pulse-Jet Cleaned Fabric Filter," *Atmos. Environ*. **14**: 845 (1980).

Koehler, John L. and David Leith, "Pressure Drop in a Pulse-Jet Cleaned Fabric Filter: Theory Calibration," *Atmos. Environ*., **17**: 1909 (1983).