Expected Backpressure

Observed backpressures can be a useful piece of information to help with the diagnosis of a troubleshooting problem. The expected/predicted backpressures are also a useful piece of information to have for methods development and choosing the best column dimensions for a given HPLC system.

Kozeny-Carman equation:

$$\Delta p = f \cdot \frac{F \cdot \eta \cdot L}{\pi \cdot r^2 \cdot d_p^2}$$

The change in backpressure is proportional to the change in flow rate, eluent viscosity, and column length. And the change in backpressure is inversely proportional to the change in the square of the column internal radius and the square of the particle diameter.

Here is a specific example that can easily be extrapolated from to relate to other cases.

Column #1 – Luna 5u C18(2) 150 x 4.6 (00F-4252-E0)
Mobile Phase: 65:35 acetonitrile:water
Flow Rate: Isocratic at 1.0 mL/min
Column Temperature: ambient
Observed Backpressure: 725 psi

Column #2 – Kinetex 2.6u C18 100 x 2.1 (00D-4462-AN)
Mobile Phase: 65:35 acetonitrile:water
Flow Rate: Isocratic at 0.5 mL/min
Column Temperature: ambient

Based on the observed backpressure of column #1 under the given conditions, we can approximate what the backpressure of column #2 will be under a different set of conditions.

1. The particle size decrease from 5um to 2.6um will approximate a backpressure increase by a factor of $(5/2.6)^2 = 3.70$

2. The decrease in column internal diameter will approximate a backpressure increase by a factor of $(2.3^2 / 1.05^2) = 4.80$

3. The decrease in the flow rate will approximate a backpressure decrease by a factor of 0.5/1.0 = 0.5 (Note: in this example, we have decreased the column internal diameter by a greater factor than the decrease in the flow rate, and therefore a higher linear velocity is being run on column #2).

4. The decrease in the column length will approximate a backpressure decrease by a factor of 100/150 = 0.667

5. The mobile phase composition and column temperature are the same, and therefore the mobile phase viscosity will be the same, not affecting the backpressure.

From these factors, we would estimate the backpressure on Column #2 to be 3.70 x 4.80 x 0.5 x 0.667 x 725psi = 4294psi. The actual observed backpressure on Column #2 was 4376psi, which corroborates our approximation.

Additional Tips:

1. Mobile phase viscosity differences were not illustrated in the above example. If the mobile phase viscosity had increased, the backpressure would also have increased proportionally. An increase in column temperature tends to decrease the mobile phase viscosity, and other solvent combinations also have different viscosities. The table below illustrates some different viscosities of some other water:organic combinations, and can be used to estimate how such a difference will affect backpressures.

Key words: HPLC, backpressure, Kozeny-Carman equation, Luna, Kinetex, viscosity

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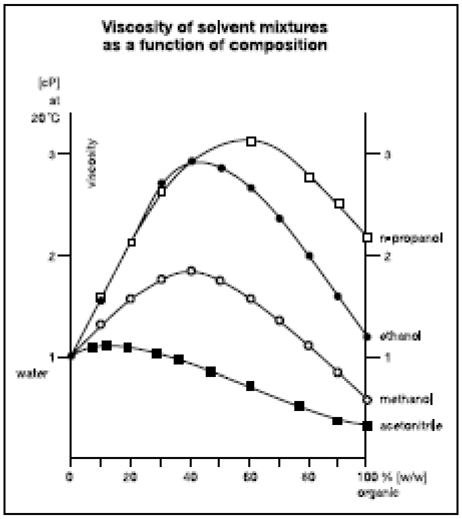
Viscosity of Solvent Mixtures as a Function of Composition



In the above example, a mobile phase composition of 65:35 water:acetonitrile was used. If however a 50:50 water:methanol mobile phase composition were used in the column #2 scenario, the backpressure would have had a further increase by a factor greater than 2 (in these proportions, the water:methanol combination has greater than double the viscosity of the water:actonitrile combination).

2. The same principles apply for gradient analysis, and the backpressure will change throughout the gradient as the mobile phase viscosity is changing.

3. HPLC system specifications can play a role in determining which column dimensions to use. Total system volume often dictates what internal diameter to use (relative to the preferred flow rate to use relative to a given column internal diameter to achieve an optimal linear velocity). The system backpressure limitations can also play a role in deciding what particle size and column length to use, as most traditional (non-UHPLC) systems have a backpressure limit of 400 bar (5800 psi) or less (and due to temporal pressure increases upon sample injection, it is typically desired to run at 100 bar less than the system limitation).

4. These calculations are approximations and will defer between various column phases and materials. The Kinetex column is state of the art core-shell technology, and other extrapolations from traditional silica based columns do not apply. Particularly efficiency, where we expect 1.7um particle-size type efficiency from the Kinetex 2.6um column (but still achieving 2.6um-like backpressures as this example illustrates).

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