Comparison of Solid Core HPLC Column Performance

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Key Words

Solid core, fused core, superficially porous, pressure, efficiency, impedance

Abstract

In this technical note the performance of Thermo Scientific™ Accucore™ HPLC columns is compared to a number of competitive columns. The experimentally derived parameters that are used for the comparison are column pressure as a function of flow rate, efficiency, and impedance.

Introduction

The use of partially porous particles, with a diameter between 2 and 3 µm, is gaining momentum, as these provide similar efficiency to sub-2 µm particles but with significantly lower column backpressures.

The Accucore HPLC column range uses Core Enhanced Technology™ to produce a 2.6 µm solid-core material with a very tight particle size distribution. The particles in the Accucore columns are not fully porous but instead have a solid silica core surrounded by a porous outer layer. The very tight particle size distribution results in columns with high permeability. Therefore, "bar for bar", Accucore columns produce improved separation efficiency when compared to fully porous materials.

Equation 1, known as the Burke-Plummer equation, shows the dependency of the pressure drop across the column on a variety of experimental parameters. The pressure is directly proportional to the column length, flow rate, and mobile phase viscosity and is inversely proportional to the square of the particle size diameter and the square of the column internal diameter ID. The interstitial porosity (the spaces between the particles that are accessible by the mobile phase) has a more complicated relationship to the pressure. There are other operating parameters that have an impact on the overall system pressure, such as the ID and length of the connecting tubing in the LC system, detector setup parameters, such as flow cell volume in UV or the ID and length of the capillary components in ESI and APCI sources in LC/MS.

Equation 1

$$\Delta P = a \frac{(1 - \varepsilon_i)^2}{\varepsilon_i^3} \frac{F L \eta}{d_c^2 d_p^2}$$

where ΔP = pressure drop across the column
a = constant (dependent on packing, normal values in the range 150 -225)
ε_i = interstitial porosity of the packed bed
F = flow rate through the column
L = length of the column
η = viscosity of the mobile phase
d_p = particle diameter
d_c = column internal diameter

The conventional approach to compare the chromatographic performance of columns is to plot normalized efficiency (HETP - height equivalent to a theoretical plate) as a function of mobile phase flow rate or linear velocity, often referred to as a van Deemter plot. This approach does have limitations, since it does not account for analysis time or pressure restrictions of the chromatographic system. Kinetic plots [1] are an alternative method of plotting the same experimental data that allow other parameters, such as pressure, to be incorporated. Therefore, we can infer the kinetic performance limits of the tested chromatographic materials. There are a variety of ways in which this data can be presented, and all of these plots are referred to as kinetic plots. In one of the most useful forms of kinetic plots, a term called impedance is used. Impedance (Equation 2) defines the resistance a compound is subjected to as it moves down the column, relative to the performance of that column. This term gives a true measure of the performance of the column as it incorporates efficiency, time, and pressure, which are critical practical considerations of a chromatographic separation.

Equation 2

$$E = \frac{\Delta P\ t}{\eta\ N^2}$$

where E = impedance
ΔP = pressure drop
t = dead time of chromatographic system
η = kinematic viscosity of mobile phase
N = efficiency

In kinetic plots, the linear velocity, conventionally plotted on the x-axis in the van Deemeter plot, is transformed into the pressure drop limited plate number. Using a maximum pressure drop for the system, any experimental set of data of HETP- linear velocity obtained in a column with arbitrary length and pressure drop can be transformed into a projected efficiency (N)-t_0. This represents the plate number and t_0-time, which could be obtained if the same chromatographic support was used in a column that was long enough to provide the maximum allowed inlet pressure for the given linear velocity.

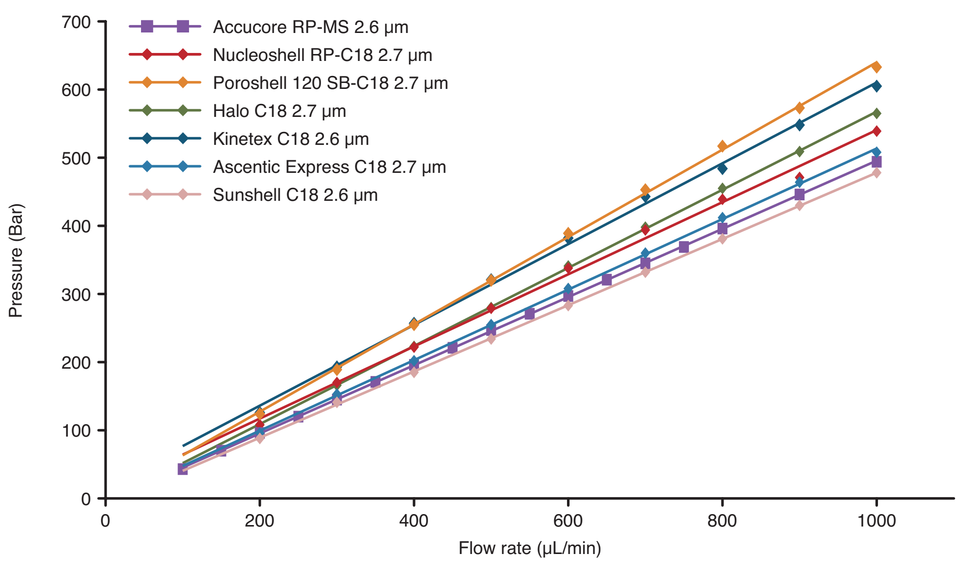

Figure 1: Comparison of column pressure for Accucore and competitor solid core columns.
All columns: 100 x 2.1 mm; test conditions: mobile phase water / acetonitrile (50:50 v/v), column temperature: 30 °C.

Material	Particle Diameter	Pore Diameter	Bonded Phase	Dimensions
Accucore	2.6 µm	80 Å	RP-MS	100 x 2.1 mm
Kinetex®	2.6 µm	100 Å	C18	100 x 2.1 mm
Poroshell® 120	2.7 µm	120 Å	SB-C18	100 x 2.1 mm
Ascentis® Express	2.7 µm	90 Å	C18	100 x 2.1 mm
Halo®	2.7 µm	90 Å	C18	100 x 2.1 mm
Nucleoshell®	2.7 µm	90 Å	RP 18	100 x 2 mm
SunShell®	2.7 µm	90 Å	C18	100 x 2.1 mm

Table 1: Columns used in this study

Column Backpressure Comparison

The solid core particles, tight control of particle diameter, and automated packing processes used in Accucore HPLC columns all contribute to low backpressures. Figure 1 shows how the column backpressure of an Accucore 2.6 µm column compares with the other solid core columns tested (Table 1). With the exception of the SunShell® 2.6 µm column (ChromaNik Technologies, Inc., Osaka, Japan) the Accucore column exhibits the lowest backpressure, across the flow rate range, tested for all of the columns tested. However, the SunShell material exhibits lower efficiencies.

Even when run at a flow rate of 1 mL/min, the backpressure of the 100 x 2.1 mm Accucore column is below 500 bar. This is 22% lower than the backpressure generated by the Poroshell 120 2.7 µm column (Agilent Technologies Inc., Santa Clara, CA, USA) under the same conditions, which is the column with the highest backpressure across the flow rate range.

Efficiency Comparison

In Figure 2, the Accucore column's speed in generating plates is compared to the competitor phases. This kinetic plot is often referred to as a Poppe plot [2]. In this type of plot the plate generation rate is plotted against efficiency. Lower values on the y-axis represent the ability to generate narrow peaks quickly. The Accucore column is the best-performing column when using this comparison, demonstrating that it provides the most efficient peaks per unit time. At the optimum point of the curve, the Accucore 2.6 µm column shows the best combination of plate generation rate / efficiency. On average, the plate generation rate of the Accucore 2.6 µm, Halo 2.7 µm (Advanced Materials Technology, Inc., Wilmington, DE, USA) and Ascentis® Express 2.7 µm (Sigma-Aldrich Co., St. Louis, MO, USA) columns are similar and 28% better than the column with the worst plate generation rate (Sunshell 2.6 µm).

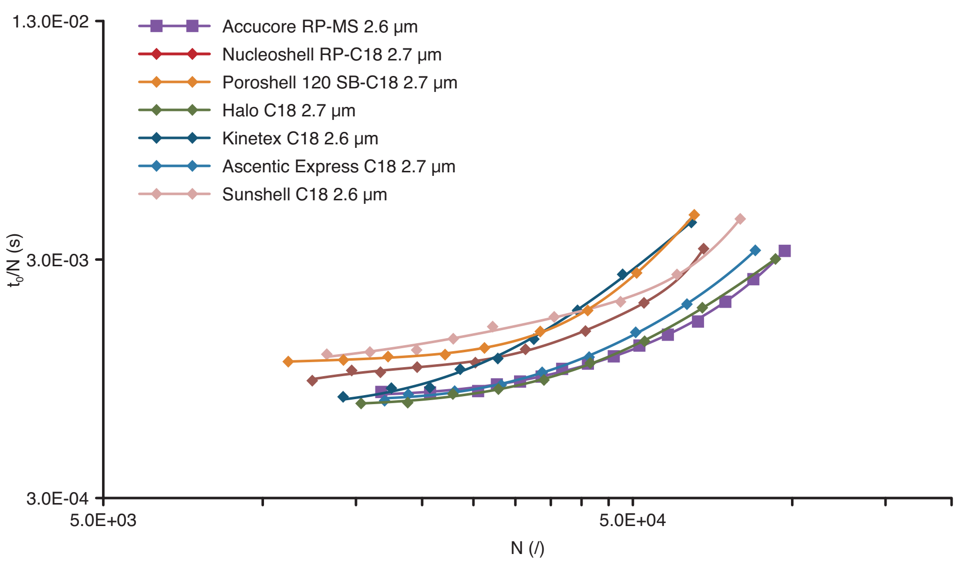

Figure 2: Performance comparison using Poppe plot (plate generation time versus efficiency) for Accucore and competitor solid core columns. All columns: 100 x 2.1 mm; test conditions: mobile phase water / acetonitrile (50:50 v/v), column temperature: 30 °C, test probes: o-xylene and theophylline (t_0 marker).

Impedance Comparison

Impedance is a term that gives a true measure of the performance of the column as it incorporates efficiency, time and pressure, which are critical parameters for chromatographers. Lower impedance values indicate faster chromatography and generation of narrower peaks at lower backpressures. The solid core particles, tight control of particle diameter, and automated packing processes used in Accucore HPLC columns all contribute to low impedance. As demonstrated in Figure 3, the Accucore column exhibits the lowest impedance of all solid core columns tested. The average impedance of the Accucore 2.6 µm column is 7% lower than the material with the second lowest impedance (Halo 2.7 µm) and 51% lower than the material with the highest impedance across the range (Poroshell 120 2.7 µm).

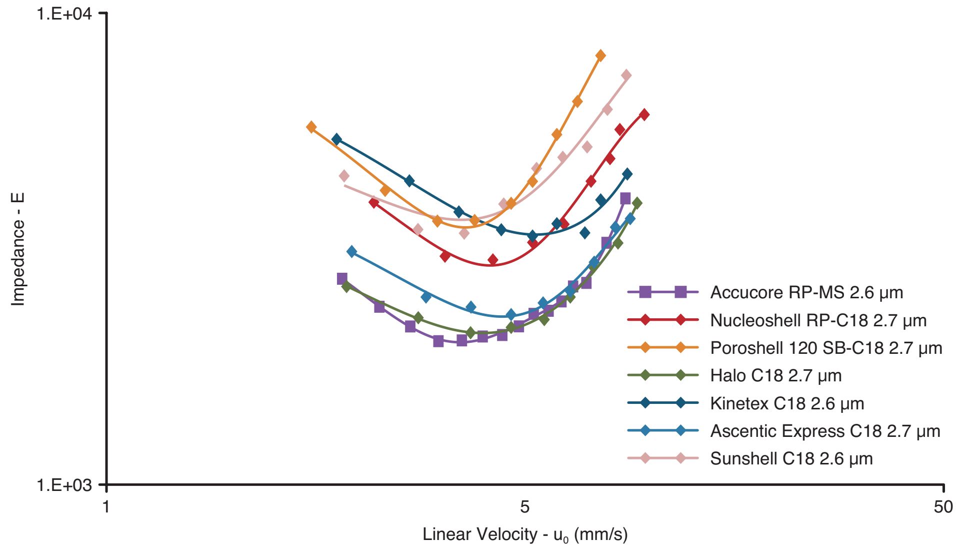

Figure 3: Performance comparison of Accucore and competitor solid core columns using kinetic plots: column impedance (E) relative to linear velocity (u). All columns: 100 x 2.1 mm; test conditions: mobile phase water / acetonitrile (50:50 v/v), column temperature: 30 °C, test probes: o-xylene and theophylline (t_0 marker).

Conclusion

- Accucore HPLC columns generate a lower backpressure than the majority of solid core competitors.
- Accucore HPLC columns generate higher efficiencies than all solid core competitors.
- Accucore HPLC columns generate lower impedances than all solid core competitors.

References

[1] G. Desmet, P. Gzil, D. Clicq, LC GC Europe, 18 (2005) 403
[2] Hans Poppe, J. Chromatogr. A, 778 (1997) 3

The data is a mixture of averages and representative data points, but is always consistent from column to column.
Testing was performed by members of our Applications R&D team.
Comparative performance may not be representative of all applications.
Purchasers must determine the suitability of products for their particular use.

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