Can I Really Enjoy the Benefits of the Latest LC Column Technology?

Stephen Luke

*LC Columns Product Manager*

*Agilent Technologies*
Organization and Laboratory Needs

Organization needs
- Increased capacity
- Shorter time to market
- Increased profitability

Laboratory needs
- Better use of resources
- Increase productivity
- Reduce costs
Laboratory Needs

Translated to liquid chromatography

Better use of resources
Increase productivity
Reduce costs

Use all the instruments in the lab
Run fast with high resolution
Get long column lifetimes
Laboratory Needs
What’s stopping you achieving them?

Better use of resources
Increase productivity
Reduce costs

Use all the instruments in the lab
Run fast with high resolution
Get long column lifetimes

Yes, but…

• I don’t all have UHPLC instruments
• I can’t / don’t want to change my methods much
• My “dirty” samples clog my columns
• My columns fail in the mobile phases we use
Superficially Porous Particles for LC

Make every LC and LC/MS in your lab work harder

Poroshell 120 2.7 µm

Poroshell 120 4 µm

www.agilent.com/chem/discoverporoshell
Laboratory Needs

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Use all the instruments in the lab
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Use All the Instruments in the Lab

Equation for Pressure Drop Across an HPLC Column

\[ \Delta P = \frac{\eta \cdot L \cdot v}{\theta \cdot d_p^2} \]

- Pressure and delay/dispersion volume are key components of instrument compatibility
- Shorter column lengths and larger particle diameters reduce column pressure

\[ \Delta P \] = Pressure Drop
\[ \eta \] = Fluid Viscosity
\[ L \] = Column Length
\[ v \] = Flow Velocity
\[ d_p \] = Particle Diameter
\[ \theta \] = Dimensionless Structural Constant
\[ \sim 600 \text{ For Packed Beds in LC} \]
Use All the Instruments in the Lab

4 µm pressures suitable for any instrument

Flow Rate and Pressure

Column Dimensions: 4.6 x 100 mm
Mobile phase A: 0.1 % formic acid in water
Mobile phase B: 0.1 % formic acid in acetonitrile
Temperature: 35°C
Pressure reading at 5% B

Application note 5991-5510EN
Use All the Instruments in the Lab

Volume Considerations for LC Systems

- The time taken for solvent to fill the delay volume represents an isocratic hold at the start of a run. For fast methods low delay volumes are required.
- Sharp (efficient) peaks have a low peak volume. Low dispersion volumes are needed to avoid broadening of low volume peaks.
- Both effects are most pronounced with narrow (2.1 mm) ID columns.
# Use All the Instruments in the Lab

<table>
<thead>
<tr>
<th>Instrument / Preference</th>
<th>Column</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHPLC</td>
<td>Poroshell 120 2.7 µm</td>
<td>Pressure 50% of sub-2 µm TPP</td>
</tr>
<tr>
<td>HPLC/UHPLC</td>
<td>Poroshell 120 4 µm</td>
<td>Typical pressure &lt; 200 bar</td>
</tr>
<tr>
<td>HPLC</td>
<td>Poroshell 120 2.7 µm</td>
<td></td>
</tr>
</tbody>
</table>
Laboratory Needs

Translated to liquid chromatography

Better use of resources
Increase productivity
Reduce costs

Use all the instruments in the lab
Run fast with high resolution
Get long column lifetimes
Increase Resolution

Fundamental Resolution Equation

\[ R_s = \frac{\sqrt{N}}{4} \left( \frac{\alpha - 1}{\alpha} \right) \frac{k}{(k + 1)} \]

To increase resolution:

- Increase retention \((k)\)
- Change selectivity \((\alpha)\)
- Increase efficiency \((N)\)
Retention and selectivity are impacted by changes to chemistry (mobile phase and stationary phase).

Using a shorter column with high efficiency will maintain resolution in a shorter run time.

Fundamental Resolution Equation

$$R_s = \frac{\sqrt{N(\alpha - 1)}}{4(\alpha + 1)k}$$
Run Fast with High Resolution

All 3 van Deemter terms are reduced with SPP

van Deemter equation:

\[ h = A + \frac{B}{v} + C \cdot v \]

- **A term** – eddy diffusion
  - Particle size & packing quality
  - Narrow particle size distribution

- **B term** – longitudinal diffusion
  - Less mobile phase in the column
  - Reduced diffusion

- **C term** – mass transfer
  - Shorter diffusion paths
  - More effect on large molecules

Lower \( h \) = higher efficiency!
Increase Resolution

4 µm gives good resolution at low pressure

Resolution vs Flow Rate
4-methyl phenol / 2-methyl phenol

Column Dimensions: 4.6 x 100 mm

Mobile phase A: 0.1 % formic acid in water

Mobile phase B: 0.1 % formic acid in acetonitrile

Temperature: 35°C

<table>
<thead>
<tr>
<th>% B</th>
<th>Time (min)</th>
<th>R_s</th>
<th>P (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1</td>
<td>1.33</td>
<td>0.8</td>
</tr>
<tr>
<td>40</td>
<td>17</td>
<td>8.5</td>
<td>6.8</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>10.5</td>
<td>8.4</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>12.5</td>
<td>10</td>
</tr>
</tbody>
</table>

Results at 2mL/min

- Eclipse Plus 1.8 um: R_s = 3.1, P = 422 bar
- Poroshell 120 2.7 um: R_s = 2.7, P = 293 bar
- Poroshell 120 4 um: R_s = 2.5, P = 169 bar
- Eclipse Plus 5 um: R_s = 2.0, P = 103 bar

Application note 5991-5510EN
Other SPP Column Performance

Poor retention and peak shape from non-Agilent columns

- Column T C18, 4 µm, 4.6 x 150 mm
  - 264 bar
  - N=6900, Tf=3.74

- Column S C18, 5 µm, 4.6 x 150 mm
  - 220 bar
  - N=12300, Tf=2.95

- Poroshell 120 EC-C18, 4 µm, 4.6 x 150 mm
  - 270 bar
  - N=15400, Tf=1.21

Mobile phase A: 20 mM K$_2$HPO$_4$/KH$_2$PO$_4$ pH 7
Mobile phase B: Methanol
Flow rate: 1.2 ml/min

1. Uracil
2. Propranolol
3. Butyl Paraben
4. Dipropylphthalate
5. Amitriptyline
Increase Resolution

4 µm column increases resolution

---

**A**
Agilent Poroshell 120 EC-C18
4.6 x 150 mm, 4 µm
Initial pressure: 135 bar

Rs = 2.31

1. Notoginsenoside R1
2. Ginsenoside Rg1
3. Ginsenoside Re
4. Ginsenoside Rb1

W_{1/2} = 0.16

---

**B**
Agilent ZORBAX Eclipse Plus C18
4.6 x 150 mm, 5 µm
Initial pressure: 90 bar

Rs = 1.51

W_{1/2} = 0.22

Notoginseng, China Pharmacopoeia, edition 2015

Application note 5991-5554EN
Run Fast with High Resolution
Shorter 4 µm column gives fast, high resolution runs

System Suitability Method Requirement: N > 4000, Rs > 11.5

- **Agilent ZORBAX Eclipse Plus C18**, 4.6 × 150 mm, 5 µm
  - USP Prescribed Column
  - L/dp = 30,000
  - 95 bar

- **Agilent Poroshell 120**, 4.6 × 150 mm, 4 µm
  - L/dp = 37,500
  - 165 bar

- **Agilent Poroshell 120**, 4.6 × 100 mm, 4 µm
  - L/dp = 25,000
  - 98 bar

**Mobile phase**: 50:49:1 MeCN:H₂O:Acetic acid
**Flow rate**: 1.2 mL/min
**Peak ID**
1. Naproxen
2. Butyrophenone

Application note 5991-5408EN
## Return on Investment

**$43K savings annually with 160% ROI / year**

**Scope**
- Number of instruments: 1
- Number of years: 5

<table>
<thead>
<tr>
<th>Method</th>
<th>Conventional</th>
<th>Fast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysese per year (1 instrument)</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Run time (minutes)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Flow rate (mL/min)</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Column lifetime (injections)</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>Development time (hours)</td>
<td>0</td>
<td>80</td>
</tr>
</tbody>
</table>

### Value

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Conventional</th>
<th>Fast</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead per instrument ($/hour)</td>
<td>$125.00</td>
<td>$20.83</td>
<td>$104,167</td>
</tr>
<tr>
<td>Cost of mobile phase purchase ($/L)</td>
<td>$62.50</td>
<td>$0.75</td>
<td>$3,750</td>
</tr>
<tr>
<td>Cost of mobile phase disposal ($/L)</td>
<td>$5.00</td>
<td>$0.06</td>
<td>$300</td>
</tr>
<tr>
<td>Columns ($)</td>
<td>$550.00</td>
<td>$0.55</td>
<td>$0.55</td>
</tr>
<tr>
<td>Total</td>
<td>$22.19</td>
<td>$13.54</td>
<td>$8.66</td>
</tr>
</tbody>
</table>

### Costs

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Conventional</th>
<th>Fast</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead per instrument ($/hour)</td>
<td>$125.00</td>
<td>$0</td>
<td>$10,000</td>
</tr>
<tr>
<td>Method development ($/hour)</td>
<td>$175.00</td>
<td>$0</td>
<td>$14,000</td>
</tr>
<tr>
<td>Instrument</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Total</td>
<td>$0</td>
<td>$24,000</td>
<td>$	ext{$43,287}$</td>
</tr>
</tbody>
</table>

### ROI

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Fast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>$0.00</td>
</tr>
<tr>
<td>Cost</td>
<td>$0.00</td>
</tr>
<tr>
<td>ROI% / year</td>
<td>160%</td>
</tr>
</tbody>
</table>
Selectivity Impacts Resolution Most

- Change bonded phase
- Change mobile phase

**Formula:**

\[
R_s = \frac{\sqrt{N}}{4} \left( \alpha - 1 \right) \frac{k}{(k + 1)}
\]
### Increase Resolution

**Choice of bonded phase selectivity - 12 chemistries**

<table>
<thead>
<tr>
<th>Best all around</th>
<th>Best for low pH mobile phases</th>
<th>Best for high pH mobile phases</th>
<th>Best for alternative selectivity</th>
<th>Best for more polar compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poroshell 120 EC-C18 2.7 µm, 4 µm</td>
<td>Poroshell 120 SB-C18 2.7 µm</td>
<td>Poroshell HPH-C18 2.7 µm, 4 µm</td>
<td>Poroshell 120 Bonus-RP 2.7 µm</td>
<td>Poroshell 120 SB-Aq 2.7 µm</td>
</tr>
<tr>
<td>Poroshell 120 EC-C8 2.7 µm, 4 µm</td>
<td>Poroshell 120 SB-C8 2.7 µm</td>
<td>Poroshell HPH-C8 2.7 µm, 4 µm</td>
<td>Poroshell 120 PFP 2.7 µm, 4 µm</td>
<td>Poroshell 120 EC-CN 2.7 µm</td>
</tr>
<tr>
<td>Poroshell 120 Phenyl-Hexyl 2.7 µm, 4 µm</td>
<td></td>
<td></td>
<td></td>
<td>Poroshell 120 HILIC 2.7 µm, 4 µm</td>
</tr>
</tbody>
</table>

Wall Chart [5991-6240EN](#)
Increase Resolution

The right selectivity

<table>
<thead>
<tr>
<th>Column</th>
<th>H</th>
<th>S*</th>
<th>A</th>
<th>B</th>
<th>C_(2.8)</th>
<th>C_(7.0)</th>
<th>F_s (pH 2.8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poroshell 120 EC-C18</td>
<td>1.02</td>
<td>0.01</td>
<td>-0.13</td>
<td>0.00</td>
<td>0.16</td>
<td>0.12</td>
<td>0.0</td>
</tr>
<tr>
<td>Poroshell 120 EC-C8</td>
<td>0.88</td>
<td>0.01</td>
<td>-0.23</td>
<td>0.02</td>
<td>0.13</td>
<td>0.09</td>
<td>6.0</td>
</tr>
<tr>
<td>Poroshell 120 Phenyl-Hexyl</td>
<td>0.75</td>
<td>-0.08</td>
<td>-0.39</td>
<td>0.02</td>
<td>0.14</td>
<td>0.14</td>
<td>13.1</td>
</tr>
<tr>
<td>Poroshell 120 PFP</td>
<td>0.63</td>
<td>-0.52</td>
<td>-0.52</td>
<td>0.43</td>
<td>-0.11</td>
<td>N/A</td>
<td>85.5</td>
</tr>
</tbody>
</table>

Hydrophobic Subtraction Model (HSM) Data provided by Dwight Stoll

$F_s$ factor describes the similarity of two column selectivities. A small $F_s$ indicates that two columns are very similar, while a large factor indicates that two columns are very different. Calculated according to the following equation:

$$F_s = \left\{ \left[ 12.5 (H_2 - H_1) \right]^2 + \left[ 100 (S_2^* - S_1^*) \right]^2 + \left[ 30 (A_2 - A_1) \right]^2 + \left[ 143 (B_2 - B_1) \right]^2 + \left[ 83 (C_2 - C_1) \right]^2 \right\}^{1/2}$$


**Reversed-phase only so Poroshell 120 HILIC not included**
Increase Resolution
The right selectivity

Cephalomannine
10-deacetyl-7-epi-paclitaxel
Pacitaxel

Agilent Poroshell 120 PFP

Peak ID
1. Impurity A
2. Impurity B
3. Paclitaxel

Agilent Poroshell 120 EC-C18

Application note 5991-6283EN
Increase Resolution

Very similar selectivity - Poroshell 120 HPH-C18 vs EC-C18

\[ R^2 = 0.9992 \]

MP-A 10mM Ammonium formate/water adj. to pH3 using Formic Acid
MP-B ACN
Flow – 0.42 mL/min
Column Temp. Ambient
1 μL injection
Detection 254 nm
Gradient:
\[
\begin{align*}
\text{time, min} & & \%B \\
0 & & 5 \\
4 & & 95 \\
5 & & 95 \\
6 & & 5 \\
7 & & \text{stop run}
\end{align*}
\]
Increase Resolution

Very different selectivity – pH10 vs pH3

R² = 0.40
Increase Resolution

Change in retention with mobile phase pH

More retention for non-charged analytes (i.e. acids at low pH and bases at high pH)

Mobile Phase: 45% Methanol, 55% 20 mM Phosphate Buffer

Column: Poroshell HPH-C18
Increase Resolution

Very different selectivity at high and low pH

Mixture of acidic and basic analytes

Application note 5991-6525EN
Advantages of High pH with LC-MS

**Improved retention, resolution and response at high pH**

Drugs of abuse analysis by LC-MS

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### Chart A

- **Conditions:**
  - 5 mM Ammonium formate
  - 0.1% Formic acid, pH 3.1, MeOH, 30 °C
  - 1 mL/min
  - Agilent Poroshell HPH C18, 3 × 100 mm, 4 µm

### Chart B

- **Conditions:**
  - 10 mM Ammonium Bicarbonate
  - pH 10.5, MeOH, 30 °C
  - Agilent Poroshell HPH C18, 3 × 100 mm, 4 µm

---

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>% B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>0.5</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>95</td>
</tr>
<tr>
<td>8</td>
<td>95</td>
</tr>
<tr>
<td>8.5</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

1. Strychnine
2. Alprazolam
3. MDMA
4. Amphetamine
5. Trazodone
6. Meperidine
7. Verapamil
8. Methadone
9. Proprafen
10. Diazepam
11. THC

---

Application note **5991-6523EN**
Other High-pH SPP Column Performance

Poor retention and peak shape from non-Agilent column

<table>
<thead>
<tr>
<th>Compound</th>
<th>HPH Column $T_f$</th>
<th>Column $T_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doxepin</td>
<td>1.68</td>
<td>2.97</td>
</tr>
<tr>
<td>Nortriptyline</td>
<td>1.36</td>
<td>1.96</td>
</tr>
<tr>
<td>Amitriptyline</td>
<td>1.25</td>
<td>2.41</td>
</tr>
<tr>
<td>Trimipramine</td>
<td>1.07</td>
<td>1.60</td>
</tr>
</tbody>
</table>

Application note 5991-6512EN
In general, Agilent Infinity modules operate over a pH range of 1 to 12.5

- pH < 2.3
  - Solvents must not contain acids that attach stainless steel

- pH > 9.5
  - Replace standard (Vespel) rotor seals in all valves with either Tefzel or PEEK seals*
  - Replace standard glass solvent inlet filters with stainless steel filters
  - Be aware that quartz flow cells in detectors will etch slowly. Do not leave high pH solvents stationary in the cells for extended periods

* Examples:
5068-0171 Rotor Seal PEEK FL for 1290 Infinity Binary Pump
5068-0170 Rotor Seal PEEK FL for 1290 Infinity High Performance Autosampler
5068-0172 Rotor Seal PEEK FL for 1290 Infinity Quaternary Pump
5068-0223 Rotor Seal PEEK for 6-Column Selector Valve
Laboratory Needs

Translated to liquid chromatography

Better use of resources
Increase productivity
Reduce costs

Use all the instruments in the lab
Run fast with high resolution
Get long column lifetimes
Costs of Short Column Lifetime

- More columns to purchase
- Disruption to workflow
- Re-work required
Get Long Column Lifetimes

Causes of Column Failure

• Blocked frits
• Contamination/blockage
• Voiding of packed bed
• Dissolution of particles
• Loss of bonded phase

Can be Avoided Using

• Wide frit porosity
• Guard columns
• Robust packed bed
• High stability particles
• Robust bonding
Get Long Column Lifetimes

>1800 Injections - no performance change

**Lifetime Test**

with Unfiltered, Undiluted Freshly Brewed Green Tea

- **Caffeine**
- **Epicatechin**
- **Epicatechin Gallate**

Peak Width at 1/2 Height, s

Number of Injections

A: 0.2% HCOOH in H₂O, B: 0.2% HCOOH in CH₃CN
0.833 mL/min

<table>
<thead>
<tr>
<th>Time</th>
<th>%B</th>
<th>°C</th>
<th>P&lt;sub&gt;max&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>10</td>
<td>40</td>
<td>550 bar</td>
</tr>
<tr>
<td>1.25</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.50</td>
<td>27</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Agilent Poroshell 120 SB-C18, 2.1 x 100 mm, 2.7 µm**

Sig=210.4nm, Ref=Off

2-µL, 3-mm micro flow cell (PN G1315-60024)

Sample: 2 µL of freshly brewed green tea
(brewed from a commercial tea bag in 6 oz of initially boiling water for six minutes)

2 µm inlet frit prevents clogging and extends column lifetime
Get Long Column Lifetimes

**Advantages of guard columns**

**Accelerated Lifetime Test**
Similac sample (milk substitute diluted 300:1) containing 2 sulfa drugs
Peak width change indicating column failure

**No Guard**
- Column failure @ inj. 70; new column required

**With Guard**
- Guard failure @ inj. 80; guard replaced
- Same column used throughout analysis

By installing a guard column when using dirtier samples, one can extend the life of their column, and utilize more inexpensive guard columns rather than analytical column replacements.
## Get Long Column Lifetimes

### Approaches for longer lifetime at high pH

<table>
<thead>
<tr>
<th>Approach</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally porous silica-hybrid particles</td>
<td>Do not have the efficiency and moderate pressure of superficially porous particles</td>
</tr>
<tr>
<td>Bonding chemistry on superficially porous silica particles</td>
<td>Do not have the lifetime of silica-hybrid particles</td>
</tr>
<tr>
<td>Chemical modification of the outer layer of superficially porous silica particles</td>
<td>Combine the advantages of silica-hybrid and superficially porous particles</td>
</tr>
</tbody>
</table>

- **Core** P120 Particle
- **Treated P120**

Utilizes a proprietary technology for particle synthesis.
Get Long Column Lifetimes

Stability at high pH

**Column:** Poroshell HPH-C18, 2.1 x 50 mm, 4 um

**Injection Details:**

- **Injection 5**
- **Injection 501**
- **Injection 1,500**
- **Injection 2,000**

**Chromatograms:**

A: 10 mM, pH 10 ammonium bicarbonate
B: Acetonitrile
25 °C, 0.4 mL/min, 2.1 x 50 mm column
220 nm, 4 nm ref off
Agilent 1290 Infinity, PEEK rotor seals

**Retention Times and % B:**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Time (min)</th>
<th>% B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 2-Hydroxy-5-methyl-benzaldehyde</td>
<td>0.0</td>
<td>5</td>
</tr>
<tr>
<td>2. 4-Chloro-cinnamic acid</td>
<td>5.0</td>
<td>95</td>
</tr>
<tr>
<td>3. Acetophenone</td>
<td>5.1</td>
<td>5</td>
</tr>
<tr>
<td>4. Quinine sulfate</td>
<td>7.0</td>
<td>5</td>
</tr>
<tr>
<td>5. Nortriptyline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Amitriptyline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Hexanophenone</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Application note:** 5991-6525EN
Other High-pH SPP Column Performance

Drifting retention times

Column: Column Y C18, 2.1 x 50 mm, 2.6 µm

Mobile phase A: 10 mM, pH 10 Ammonium Bicarbonate
Mobile phase B: Acetonitrile
Flow rate: 0.4 ml/min
Temperature: 25 C

Injection 1
Amitriptyline

1. 2-Hydroxy-5 methyl-benzaldehyde
2. 4-Chloro-cinnamic acid
3. Acetophenone
4. Quinine Sulfate
5. Nortriptyline
6. Hexanophenone
7. Amitriptyline

Injection 200
Poroshell 120
Make every LC and LC/MS in your lab work harder

Efficiency 90% of < 2 µm TPP
Pressure 50% of < 2 µm TPP
12 chemistries, including HPH
2 µm inlet frit

Poroshell 120 2.7 µm

Poroshell 120 4 µm

Efficiency 2x 5 µm TPP
Pressure often below 200 bar
7 chemistries, including HPH
2 µm inlet frit

www.agilent.com/chem/discoverporoshell

TPP = totally porous particle
Summary

- The pressure and peak widths of Poroshell 4 um particles allow you to use all the instruments in the lab
- High efficiency Poroshell particles and the right bonded phase selectivity enable fast runs with high resolution
- 2 µm inlet frits and innovative chemistries like HPH provide long column lifetimes – even at high pH
- You really can enjoy the benefits of the latest LC column technology

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