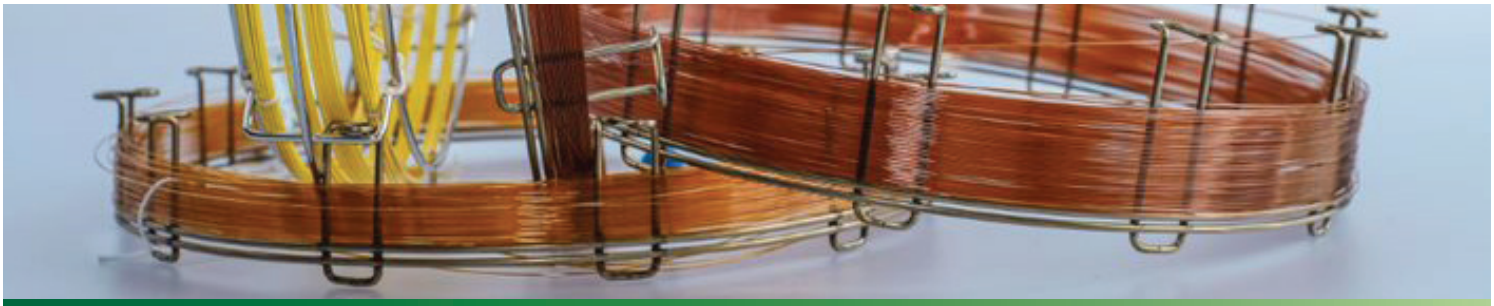

GC COLUMN SELECTION GUIDE

Introduction

Choosing which chromatography column to install is perhaps the most impactful decision a chromatographer routinely makes. Since the separation of compounds by GC is governed by a molecule's partitioning properties between the carrier gas and the column's stationary phase, the careful selection of which column to use not only impacts chromatographic performance, but sample throughput and capacity as well. However, rather than considering whether a better column choice might be available, chemists might select whichever column type is most familiar, or simply whichever column is specified in a transcribed analytical method. Without considering whether there may be a more suitable column for the application, the chromatographer can never be certain whether they have maximized their instrument's performance. We, at PerkinElmer, believe that chromatography and education go hand-in-hand. This column selection guide outlines typical applications for each column so that you can be sure the chemical makeup of your sample and the chemical makeup of your column are perfectly aligned, and details how column dimensions can be optimized for the best balance of analytical performance and speed.

Stationary Phase

When selecting a column, the analytical chemist's single most essential choice is that of the column stationary phase. The chemical makeup of the stationary phase is what governs the selectivity parameter, determining which compounds are best retained and the order in which they elute. With non-polar phases, the separation is loosely driven by compound boiling point. However, to resolve compounds with similar boiling points (e.g., isomers), highly selective and/or polar stationary phases are often required. Figure 2 lists a select few column stationary phases in order of increasing McReynolds value, a.k.a. polar characteristic. Whereas some stationary phases interact with analyte molecules primarily through Van der Waals forces (e.g. 100% dimethylpolysiloxane), other phases select for π-π interactions and induced dipoles (e.g. 5% diphenyl-95% dimethylpolysiloxane), and others still select for more polar bonds (e.g. polyethylene glycol). Correspondingly, these phases are each optimized for different chemical classes. Table 1 lists the available PerkinElmer Elite GC capillary columns, each with their own stationary phase and optimized analyte chemical classes and/or applications of choice.

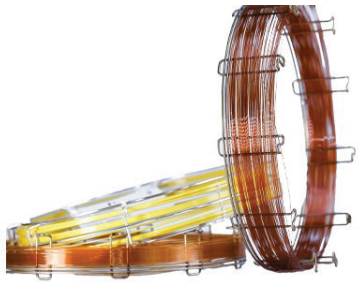

Figure 1: GC Capillary Column.

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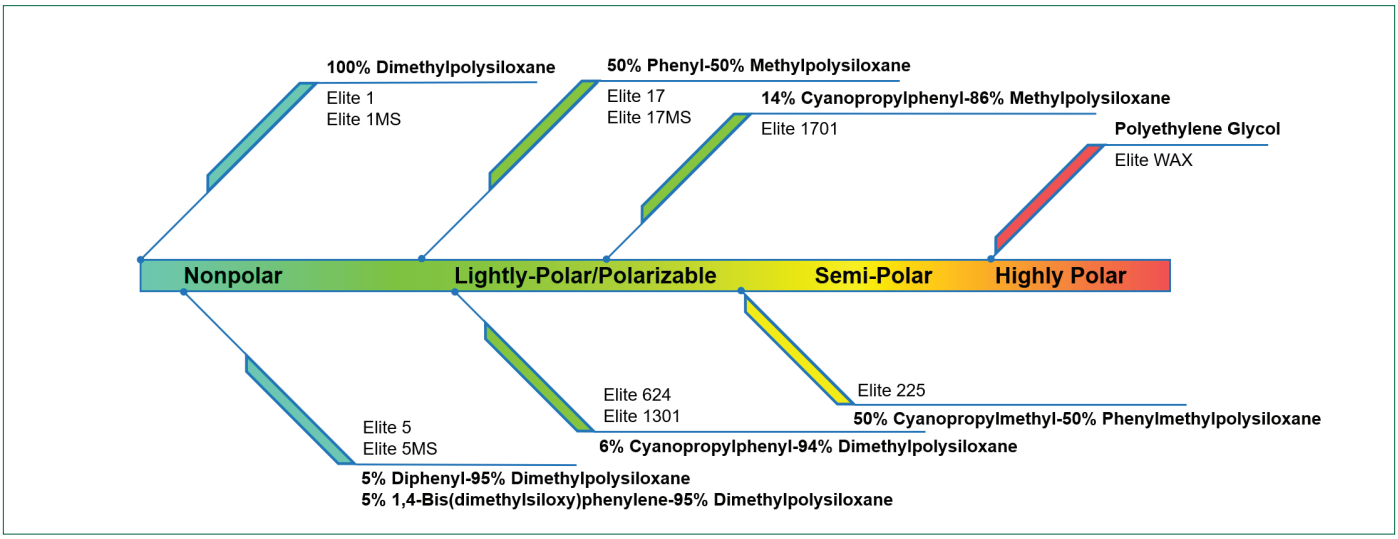

Figure 2: Example chemical compositions and corresponding PerkinElmer brand columns for capillary GC stationary phases, listed from nonpolar (left) to polar (right).

Some stationary phases are offered in both standard and "MS" forms. This distinction generally refers to the method of column manufacture, with MS columns having a lower bleed characteristic and a trade-off of higher production (and therefore consumer) cost. The ultra-low bleed quality makes MS columns ideal for GC/MS, since high bleed will degrade mass spectrometer performance over time. However, regardless of which detector is used, MS columns should be utilized for all applications requiring low bleed, or for any analysis pushing the instrument's limit of detection.

Table 1: Typical applications using PerkinElmer Elite GC capillary columns. The Elite range of MS columns (e.g. Elite-5ms) are engineered for extremely low bleed for high sensitivity MS detectors, providing optimum sensitivity, but may also be used for other detectors.

Column	USP Code	Application
Elite-1 and Elite-1ms	G1, G2, G38	General purpose column. Non-polar petrochemical samples such as detailed hydrocarbon analysis, hydrocarbon gases, petroleum oxygenates, petroleum aromatics, fuels, waxes, oils, sulphur compounds, mercaptans and carbon disulphide. May also be used for polychlorinated biphenyls (PCB; e.g. Aroclor mixes), flavours, fragrances, essential oils, toxins, chlorofluorocarbons, arson accelerants, pesticides, amines and solvent impurities. Can also be used for residual solvents in packaging materials.
Elite-5 and Elite-5ms	G27, G36	General purpose column. Drugs, pesticides (including organochlorine and organophosphorus), hydrocarbons (including chlorinated), total petroleum hydrocarbons (TPH), PCBs (e.g., Arochlor mixes), PAHs, phthalates, phenols, amines, essential oils, semi-volatiles and solvent impurities.
Elite-17 and Elite-17ms	G3	Pesticides, herbicides, PAHs, phthalate esters, sterols, and rosin acids.
Elite-35 and Elite-35ms	G42	Organochlorine pesticides, PCB, herbicides, pharmaceuticals, sterols, phthalate esters and rosin acids. Popular confirmation column for pesticides and herbicides, in conjunction with an Elite-1701. The higher phenyl content results in useful elution order and retention time changes. The Elite-35ms, specifically, is particularly useful for Method EN 14362 (determination of aromatic amines derived from azo colorants). May also be used for the separation of cannabinoids.
Elite-200	G6	Phenols, and with sensitive detectors such as ECDs (at lower column temperatures), NPDs, and MSDs. It is a good general-purpose column for solvents, Freon fluorocarbons, alcohols, ketones, silanes, glycols, and drugs of abuse. An excellent column for confirmation of phenols, nitrosamines, organochlorine pesticides, chlorinated hydrocarbons, and chlorophenoxy herbicides when paired with an Elite-5 column. A good alternative to the more polar WAX column if higher GC oven temperatures are required (e.g. for analysis of impurities in phenol; partial separation of m- and p- cresol).
Elite-624 and Elite-624ms	G43	Highly selective for residual solvents making them a great choice for USP<467>. Well suited for volatile organic compounds in water and soils with purge and trap (EPA Methods 8260, EPA 5030, EPA 5035, EPA624, EPA 524.2). Especially well-suited for EPA Method 524.2 since it resolves 2-nitropropane from 1,1-dichloropropanone, which share quantification ion m/z 43 and must be separated chromatographically.

Column	USP Code	Application
Elite-1301	G43	Commonly used for the analysis of residual solvents, alcohols, oxygenates and volatile organic compounds.
Elite-1701	G46	General purpose column for the analysis of alcohols, oxygenates, PCB congeners (e.g. Aroclor mixes), and pesticides. Mix of cyano and phenyl functional groups increases the polarity and offers a different elution order relative to less polar Elite-1 or Elite-5 columns. An Elite-1701 column is ideal for confirmation analysis in combination with an Elite-35 or Elite-5 column.
Elite-225	G7, G19	General purpose column for the analysis of FAMEs, carbohydrates, sterols and flavour compounds.
Elite-WAX	G14, G15, G16, G20, G39	Commonly used for the analysis of polar compounds like alcohols, glycols, aldehydes and FAMEs. May be used as a confirmation column for residual solvents when working according to USP<467>, as it provides different selectivity to the Elite-624.
Elite-WAX ETR	G14, G15, G16, G20, G39	Wide applicability including FAMEs, flavor compounds, acrolein/acrylonitrile (EPA 603), oxygenated compounds, and impurities in water matrices. Low bleed WAX column that exhibits extended lifetimes even when repeatedly heated to 250 °C.
Elite-SimDist	--	Non-polar column for simulated distillation methods; elution order is a function of boiling point for a homologue series of alkanes. Replicates medium and heavy hydrocarbon distillation.
Elite-BAC1 and Elite-BAC2	--	Ideal for blood alcohol analysis.
Elite-VMS	--	Faster analysis for separating volatile organic compounds using MS detection.
Elite-XLB	--	Analysis of pesticides, PCB congeners (e.g., Aroclor mixes) and PAHs.
Elite-Volatiles	--	Excellent resolution, and fast analysis times for volatile organic pollutants.
Elite-CLPesticides	--	Specially designed to overcome the coelutions and analyte breakdown typically encountered in chlorinated pesticide analyses for U.S. EPA methods 8081, 608, and CLP. PCB analysis.
Elite-502.2	--	Analysis of volatiles by U.S. EPA method 502.2
Elite-RX	--	Ideal for drugs of abuse.
Elite-Betacyclodextrin	--	General-purpose chiral, chiral compounds in essential oils.
Elite-608	--	Analysis of semi volatile pesticides by U.S. EPA method 608.
Elite-TPH	G1	Analysis of total petroleum hydrocarbons.
Elite-PONA	--	Detailed analysis of petroleum naphtha.
Elite-FFAP	--	Analysis of free fatty acids.
Elite-Amine	--	Application-specific column for amines and other basic compounds, including alkylamines and di/triamines.
Elite-23/2330	G5, G8, G48	Analysis of cis/trans isomers in FAMEs and dioxins. Preferred column for cis/trans fatty acid profile analysis of edible oils.
Elite-2560	G5	Application-specific column for better separation of cis/trans FAMEs.
Elite-MTBE	--	Analysis of methyl t-butylether and other oxygenates.
Elite-Molesieve PLOT	--	Light gas analysis: H_2, Ar, O_2, N_2, CH_4, CO (Note: avoid column exposure to CO_2 and H_2O).
Elite-Q PLOT	--	Analysis of light gases and hydrocarbons.

Column Length

Most commonly, analysts use 30 m columns for their separations. When we lengthen our analytical column, we enhance both efficiency and resolution. This may at first seem ideal! After all, who wouldn't appreciate the enhanced separation power of twice the theoretical plates when migrating from a 30 m to a 60 m column? Unfortunately, doubling column length does not double the resolution: resolution increases proportionally with the square root of the length. And like all things in chromatography, increasing length comes with costs as well as benefits.

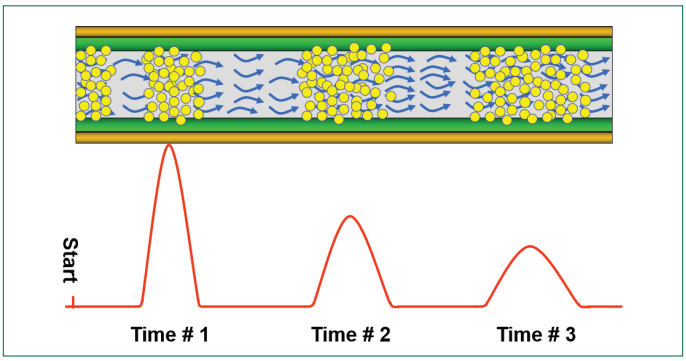

Figure 3: Depiction of band broadening at the start (Time 1), middle (Time 2), and end (Time 3) of a method. Analyte molecules spread out over the course of a chromatographic separation. This phenomenon must be artfully managed especially when developing methods on longer columns.

Due to a combination of Brownian Motion and the multi-path effect, what starts off as a narrow cluster of molecules at the column head will always broaden by the time these molecules elute, see Figure 3. Columns ≥ 60 m will have generally wider peaks, lesser peak height, and therefore diminished sensitivity. When steep temperature ramps, i.e., > 20 °C/min, are included in the method, the oven will often get so hot that many analytes barely interact with the stationary phase by the time they reach the latter portion of the column. On the other hand, for early eluting compounds (i.e., k' < 3) a longer analytical column can enhance resolution whilst minimizing negative effects of the increased length. For these reasons, as well as increased analysis times, the selection of column length should be made carefully.

Increasing Column Length

Benefits

- Greater efficiency, plate count
- Greater resolution
- Enhanced separation of early eluting compounds
- Less impact of lost column length due to column cutting

Deficits

- Shorter, wider peaks
- Reduced sensitivity
- Longer analysis times
- Steep temperature ramps can reduce efficacy

Column Inner Diameter

The two most common I.D.s used in gas chromatography are 0.25 mm and 0.32 mm. Primarily, column I.D. balances two competing parameters: column efficiency (i.e., theoretical plates) against sample capacity. When we narrow our analytical column, efficiency increases, allowing for faster separation of analytes and sharper, taller peaks. For instance, when developing methods to separate especially complex multicomponent mixtures, the narrowest column possible should be chosen. Counterbalancing this benefit, however, is that sample capacity decreases exponentially with narrower diameter, see Figure 4. Whereas wide- and mega-bore columns can withstand high-concentration injections of hundreds to thousands of nanograms-on-column, the ability to resolve individual components is hampered. For "simple" samples with few components and for well-resolved analytes, a wide-bore column can obviate complex sample prep/dilutions and expedite analysis times.

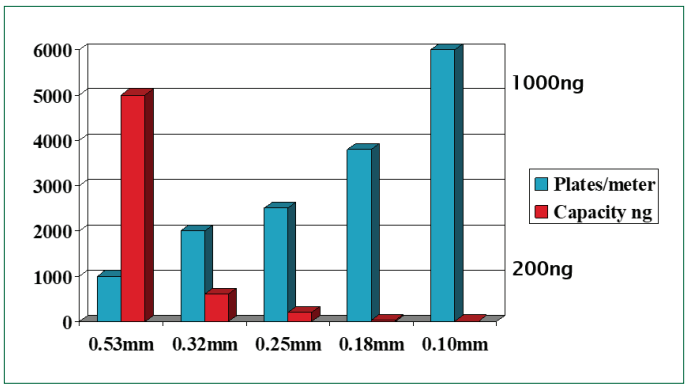

Figure 4: Cost/benefits of modifying column inner diameter. When we increase the inner diameter, the acceptable compound mass-on-column increases exponentially at the costs of plates-per-meter.

Increasing Column Inner Diameter

Benefits

- Greater sample capacity
- Wider concentration range
- Shorter analysis times
- Less sample preparation

Deficits

- Reduced efficiency, plate count
- Reduced resolution
- Shorter, wider peaks
- Greater gas consumption

Column Film Thickness

The stationary phase, i.e., film, governs partitioning chemistry during the analytical separation. It is therefore no surprise that manufacturers offer a wide range of stationary phases with varying film thicknesses. Whilst a film of 0.25 µm is often considered "standard", the ideal film thickness may vary for each application or phase.

Figure 5 depicts analyte molecules partitioning between mobile and stationary phase, both 0.25 µm and 1.00 µm film thickness. Since mass transfer of analytes can only occur at the interface between mobile and stationary phases, thicker films, with their smaller surface area-to-volume ratio, result in greater height equivalent of theoretical plate (HETP) and lower efficiency. On the other hand, volatiles that may be poorly retained on a 0.25 µm column will often have superior resolution on thick film columns.

Increasing Column Film Thickness

Benefits

- Greater sample capacity
- Greater resolution of some volatiles
- Reduced interaction with tubing, tailing

Deficits

- Greater column bleed
- Reduced resolution of some semivolatiles
- Reduced maximum operating temperature
- Reduced efficiency, plate count

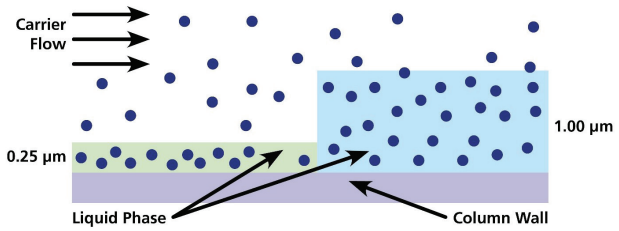

Figure 5: Analyte molecules (blue spheres) dissolve deeper into thicker films, increasing HETP whilst enhancing retention of volatile compounds.

Phase Ratio

At the convergence of column I.D. and film thickness, df, is the phase ratio, β. This parameter expresses the area ratio of carrier gas versus stationary phase.

$$\beta = \frac{I.D.\ (\mu m)}{4 \times df\ (\mu m)}$$

Examples:

30 m x 0.25 mm x 0.25 µm	β = 250
60 m x 0.53 mm x 0.25 µm	β = 530
30 m x 0.53 mm x 1.00 µm	β = 135

Often, analysis can be transferred between columns of different diameter by adjusting to similar phase ratios. In general, columns where β < 100 will be superior at resolving highly volatile compounds, columns where β > 400 are superior at resolving high molecular weight compounds, and those in between (100 < β < 400) are the most versatile, i.e., general purpose.

A Message from PerkinElmer

It is our hope that by using this resource you can ensure your analytical separations are as robust as needed to meet the rigorous standards set forth by your laboratory. By familiarizing yourself with the principles of method optimization, your lab could improve separations and save hours in extraneous method run times, driving efficiency and productivity. As the analytical column is the heart of the GC, optimizing the right method for the right column isn't just good science – it's good for your laboratory's bottom line.

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