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Column Selection Guideline

A column is of course, the starting and central piece of a chromatograph. An appropriately selected column can produce a good chromatographic separation which provides an accurate and reliable analysis. An improperly used column can often generate confusing, inadequate, and poor separations which can lead to results that are invalid or complex to interpret.

There are over 10,000 compounds that can be analyzed by GC and over 400 GC capillary columns. It is a challenge for a column manufacturer to give detailed column selection guidelines to meet such a wide variety of applications. In spite of this challenge, we would like to offer our many years experience and expertise to help you choose the proper column for your application.

Column Characteristics

A column is characterized by its stationary phase and dimensions: column ID, length, and film thickness (or more precisely, phase ratio). All of these variables directly affect separation to different degrees in elution order, retention time, peak resolution, and peak shape/height. Additionally, column performance is largely characterized by column inertness, plate numbers and column bleed in a chromatographic application. Therefore, indirectly or directly impacting how accurate and reliable the analysis performs. Among these variables, stationary phase is the most influential and effective variable that leads to a good separation on a properly maintained column.

Stationary phase

When selecting a column, first determine the samples characteristics to match the columns stationary phase. Stationary phases are in general divided into 3 categories: 1) non-polar, 2) mid-polar and 3) polar. Stationary phases are further categorized by siloxane (non-polar and mid-polar) and polyethylene glycol (PEG or polar), based on the stationary chemical composition and WCOT (Gas-liquid partition chromatograph) and PLOT (Gas Solid absorption chromatograph) based on the separation mechanisms. Table I lists the common stationary phases.

	Separated compounds	Comment
Non-Polar phases		
GsBP-1, GsBP-5, GsBP-1MS, GsBP-5MS	Most compounds, elution order by boiling point order, primary C-C or C-H bonds compounds	Different elution orders of polar or polarized compounds, such as alcohol, from polar columns
Mid-polar phase		
GsBP-35, GsBP-50, GsBP-1301, GsBP-1701, GsBP-624	Most polar C-C or C-H bond compounds containing Br, Cl, F, N, O, P, S atoms.	Improved separation of polar compounds from non-polar compounds over non-polar columns
Polar phase		
GsBP-Inowax, GsBP-FFAP, GsBP-Carbowax	Most polar C-H or polarized compounds, such as aromatic rings	Different elution orders of polar compounds from non-polar/mid-polar columns
PLOTs		
Al2O3	Light hydrocarbons C1 to C6/C10, alkanes, alkenes, alkynes and benzene rings, or C-Halogenic bonded gases	Improved separations over non-polar columns
Molesieve	Fixed gas separation: H2, noble gases, sulfur gases, nitrous gases, oxygen, nitrogen, SF6, methane, ethane and ethylene, CO	Just gaseous state compounds below ambient temperatures
Porous Polymers PLOT Q, U,	Light hydrocarbons C1 to C3/C6, CO2, CO, water, C1 to C4 alcohols, acids, amines, sulfurs, C1 to C3	Very versatile separations with not satisfactory resolution, inertness issues
GasPro	Light sulfur compounds, CFCs, from light hydrocarbons	Elution order interference with hydrocarbons

The commonly used separation principle associated with stationary phases is: non-polar columns retain non-polar compounds and polar columns retain polar compounds. However, this principle can be improperly cited leading to the use of improper columns. Most complex and difficult samples to analyze contain non-polar and polar compounds for example gasoline blended with denatured ethanol.

Over the past few decades, statistics of GC applications shows a popularity of non-polar phase columns compared to polar or mid-polar phase columns. Typically, non-polar columns, such as the 5MS column, can capture over 50% of applications and analyses. While polar or mid-polar columns e.g. PEG phase columns may capture about 25% of applications. There is an increasing trend of non-polar columns to be used for volatile chemicals including solvents and drugs.

As a general rule, non-polar columns should be selected first, and polar columns should be used for less complicated samples (less varied in chemical structure). For separation confirmation purposes, polar and non-polar stationary phase columns should be used for the same sample.

Table II lists the stationary phase recommendations for some compound separations

Sample Compounds of Interest	Recommended stationary phases	Comment
Air pollution	GsBP-1, GsBP-GasPro, GsBP-PLOT Q, GsBP-5	
Alcohol as major compounds	GsBP-1 or GsBP-5,	Good separation in C1 to C3 alcohols
Alcohols	GsBP-Inowax, Carbowax, FFAP	Limited separation of ethanol with isopropyl alcohol
Anesthic gas or breath gas	GsBP-GasPro GsBP-5MS	

Sample Compounds of Interest	Recommended stationary phases	Comment
Aromatics	GsBP-Inowax / FFAP, GsBP-Al2O3 PLOT	
Biodiesel	GsBP-Inowax,GsBP-5MS, GsBP-624	
Dioxines	GsBP-5MS	Some critical separation issues
Drug abuse	GsBP-5, GsBP-Inowax, GsBP-1	
Drugs, natural product extract	GsBP-5, GsBP-1, GsBP-50MS	
FAMEs	GsBP-5MS, GsBP-Inowax, GsBP-624	Limited separations of isomers in C22-C24s. lifetime issues
Food preserve additives	GsBP-5, GsBP-FFAP	
Gasoline	GsBP-1, GsBP-Inowax	DHA or oxygenates
Life science research	GsBP-5MS, GsBP-FFAP	Metabolism study
PCBs, PBDEs	GsBP-5MS	Some congener separation resolution issue
Pesticides	GsBP-5MS GsBP-1701	
Petroleum streams	GsBP-AL2O3 PLOT, GsBP-5, GsBP-1	
Volatiles	GsBP-5, GsBP-1, GSBP-624	Co-elution or limited resolution issue for some volatiles
Water analysis, Volatiles	GsBP-624, GsBP-5	
Wine/Liquor	GsBP-FFAP, GsBP-Inowax, GsBP-1	

Stationary phase selection should also include the instrument/instrumentation conditions, such as the detector, carrier gas, and sample size. If both selection and detection are not main concerns, a stationary phase with low response to the detector should be used. For example, a cyano phase such as a 1301, 1701, 624, or fame column should not be used on a GC-NPD. A lower bleed column phase such as -1MS or -5MS should be used as much as possible to minimize the effect of a baseline rise on low detection limit. If the purity of the carrier gas is in question or the instrument has gas leaking issues, high temperature limit stationary phase should be considered first to minimize early phase damage. Finally, unless necessary, the bonded phase should always be used over non-bonded and non-crosslinked phases to avoid column performance degradation caused by the sample and the sample size.

When the separation or the peak identification is very complex, a non-polar phase column should be used as often as possible; the elution order on this type column is relatively simpler than the elution order on a polar phase column.

Finally, for applications that require validation, both polar and non-polar phase columns should be used to confirm peak identification or verify separation. Common pairs of columns are -5MS and -1701 or -35 for pesticides, --5MS and -624 or –VMS for residue solvents, PEG and Cyano phase for alcohol separations, and FAME analysis, -1, and PEG for oxygenates in gasoline.

Column ID

Column Internal Diameters (ID) standard sizes are 0.20mm, 0.25mm, 0.32mm, and 0.53mm. Less popular IDs are 0.1mm and 0.8mm. 0.25mm. ID columns are often referred to as capillary columns and are able to separate many critical compounds, while 0.53mm columns are referred as replacements of packed columns for large sample size applications.

Column ID plays two contradicting roles in separation. With decreasing column ID, there are increased plate numbers (increased efficiency) and decreased sample loading capacities. When a column is overloaded with sample, the plate number is decreased greatly. Often times we have to make compromises. In most cases, there is no optimum column ID for an application.

As a general rule, a column with a larger column ID (e.g., 0.53mm ID) should be used for trace level impurity analysis or used with the Head Space (HS) application. If the separation needs to be improved or a critical separation needed, a column with a smaller column ID (0.25mm or 0.20mm) should be used. Each industry or demography has its own preference or internal standard of column ID. A column with a 0.32mm column ID is a popular choice because of its compromise in sample loading capacity and efficiency.

Columns with a 0.25mm column ID have become very popular in modern GC applications. The 0.25mm column ID has been estimated to account for over 50% of applications. It provides an excellent balance in separation efficiency and sample loading capacity. It is used widely in the environmental, food, and legal industries. In most cases, 0.25mm columns exhibit synergies of MS columns and are suitable for most GC-MS applications.

Columns with smaller columns IDs such as 0.10mm and 0.20mm often are used for fast separations. Additionally, they can improve analysis by the column features relating to column inertness, efficiency, and column bleed. Relatively speaking, columns with 0.32mm and 0.53mm column IDs are more inert than columns with 0.20mm and 0.25mm column IDs. Whenever there is a need for column inertness, columns with larger column IDs should be considered. When the instrument is limited in inlet pressure control, columns with larger column IDs are the first choice. When the column carrier gas quality is in question or instrument condition is poorly kept, columns with larger column IDs (0.32mm or 0.53mm) should be considered to prolong the column lifetime. When the column bleed is a concern, columns with smaller column IDs along with columns that have thin film thicknesses should be used.

Column Length

Column length increases retention times (analysis time) and, to a lesser degree, separation efficiency (by doubling plate number). Industry standardized lengths are 5m, 7.5m, 10m, 12.5m, 15m, 25m, 30m, 50m, 60m, 75, 100m, and 105m. The most popular column length is 30m.

For fast analysis, it is necessary that the column have a proper column ID and short column length (e.g. 5—15m x 0.25mm). With these specs, it is very possible to

generate excellent separation and results with adequate analysis times.

When there is a need to improve a separation by increasing resolution, longer length columns, such as 60m or 100m, can be used. The resolution is improved by the square root of the length; a 60m column only increases the resolution by 40% over a 30m column, while the analysis time is doubled.

Columns with longer lengths like 50m, 60m and 100m columns are often used for volatile applications in attempting to improve separations. This becomes prevailing in gaseous sample applications or detailed hydrocarbon analysis.

Columns with longer lengths often have issues with column inertness, column bleed, and column efficiency. These columns also require high carrier gas pressures or different carrier gases altogether (varying from nitrogen to hydrogen/helium).

Film Thickness

Industry standardized film thicknesses are 0.1um, 0.15um, 0.25um, 0.5um, 1.0um, 1.5um, 3um, 5um. Some odd film thicknesses such as 0.33um, 0.88um, 2.65um are historical convention. 0.25um, 0.5um and 1um film thickness are the most popular ones.

Film thickness plays two roles, increasing the retention time, and increasing the sample loading capacity. Film thickness also affects the column operation temperature, analysis time, and result accuracy/reliability. A column with thin film thickness such as 0.25mm x 0.1um gives a very fast separation, and sometimes may increase separation resolution, and decrease the column bleed at very high operation temperatures. Sometimes column inertness also becomes a noticeable issue. Column sample loading capacity can also be decreased greatly, weakening the benefits of a quicker and improved resolution.

0.25um x 0.25mm ID, 0.5um x 0.32mm ID, 1um or 1.5um x 0.53mm ID columns often give a better balance in separations and analyses requiring retention, resolution, separation, inertness, and column bleed.

Film thickness is related to column ID by the phase ratio (β). On two columns of the same phase ratio and the same stationary phase, but different IDs, the separation or retentions would be the same or similar under the same temperature conditions. For an example, 0.25mm x 30m x 0.25um GsBP-5MS (β =250) will have similar retention times and separations to a 0.53mm x 30m x 0.5um column (β=265). Hence, this provides an alternate solution to a column that is not readily available.

Customer-made columns

When you cannot find an existing column that meets your needs, you may inquire about a customer-made column. Except for the column's stationary phase, all column dimensions (column ID, length, and film thickness) can be specifically designed by you or with our collaboration. Additionally, two columns can be connected or a guard column to an analytical column. For details, please contact us.

Sample Characteristics

The sample used for analysis is an important factor in column selections. A sample can be characterized in many ways. The following table lists a few general guidelines.

Physical property	ID (mm)	Length (M)	Film thickness, (um)	Comment
Solid	0.53	30		
Liquid	Any			
Gas	0.53	30, 60	1.5 to 5	
Clean sample after preparation				
	0.25, 0.32	30	0.25	
Dirty sample or raw sample	0.53, 0.32	30	0.25 to 1.5	Guard column, 0.53mm ID
High boiling point compound	0.25, 0.32 and 0.53	15, 30	0.1, 0.25	Guard column, 0.53mm ID
Complicate sample, non-polar/polar compounds	0.20, 0.25	15 30, 60, 100	0.1, 0.25	
Unstable or reactive compounds, such as TNT	0.25, 0.53	5, 10, 15	0.1, 0.25, 1	
Aqueous sample	0.25, 0.53	15, 30, 60	1, 1.5, 3	Guard column

Conventional Wisdom for Column Selection

- Make use of any available information on methods, regulations, and experimental results, that can be acquired from public domains and column manufacturers
- Know your sample and your application requirements
- Start with a simple column such as a non-polar phase 30m standard length and 0.25mm column ID
- Most known separations can be achieved, either completely or partially, with any popular columns
- If having trouble, use a trial and error approach and collaborate with the column manufacturer to save time and money
- Accumulate your experience and knowledge and share it with others.
- Optimization of separations including column separation is not an easy process, as variation from brand names and batches affect separation. So, keep in mind there is no perfect fit.
- There are differences between various GC name brands which yield varying results, such as elution order, separation/resolution, number of peaks, and often result accuracy.