Understanding the GC Inlet: Which Type is Most Appropriate for your Method?

Mark Sinnott
Agilent Technologies
Application Engineer
April 22, 2021

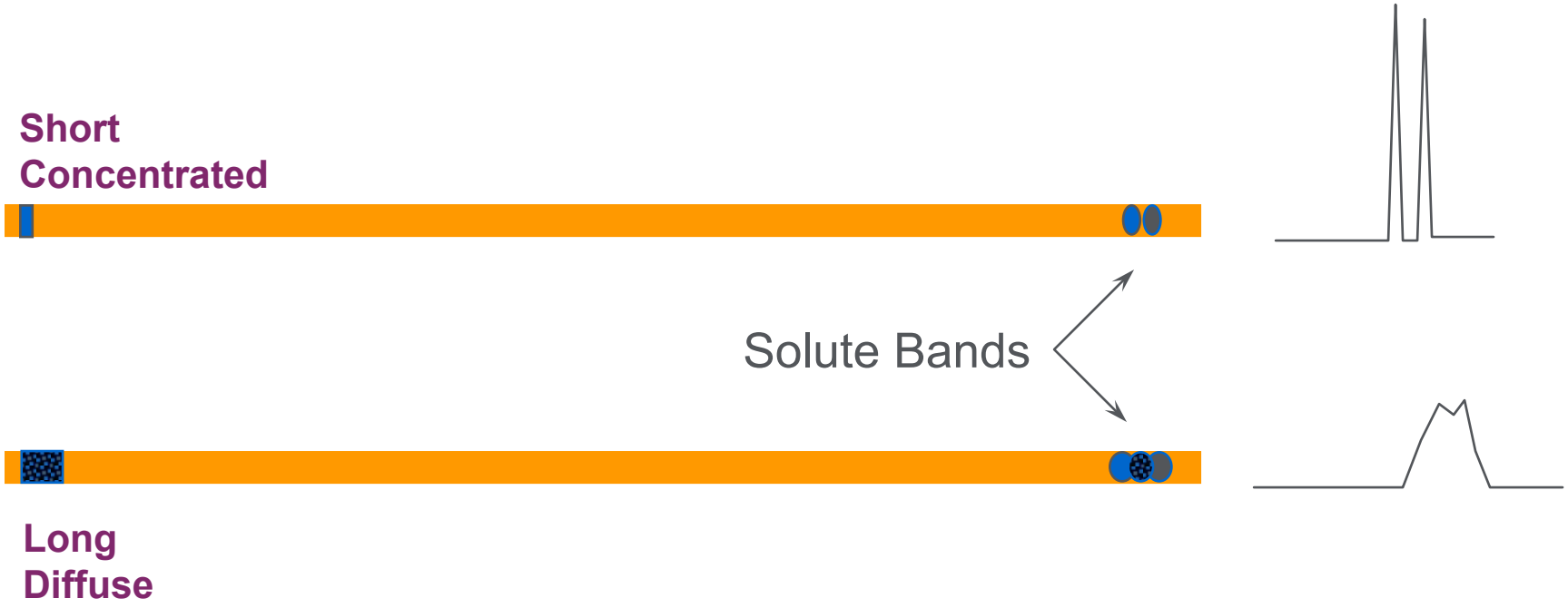
Agilent
Trusted Answers

DE44305-5966666667

Sample Injection Goals

- Introduce sample into the column
- Reproducible
- Minimize efficiency losses
- Representative of sample

Influence of Injection Efficiency



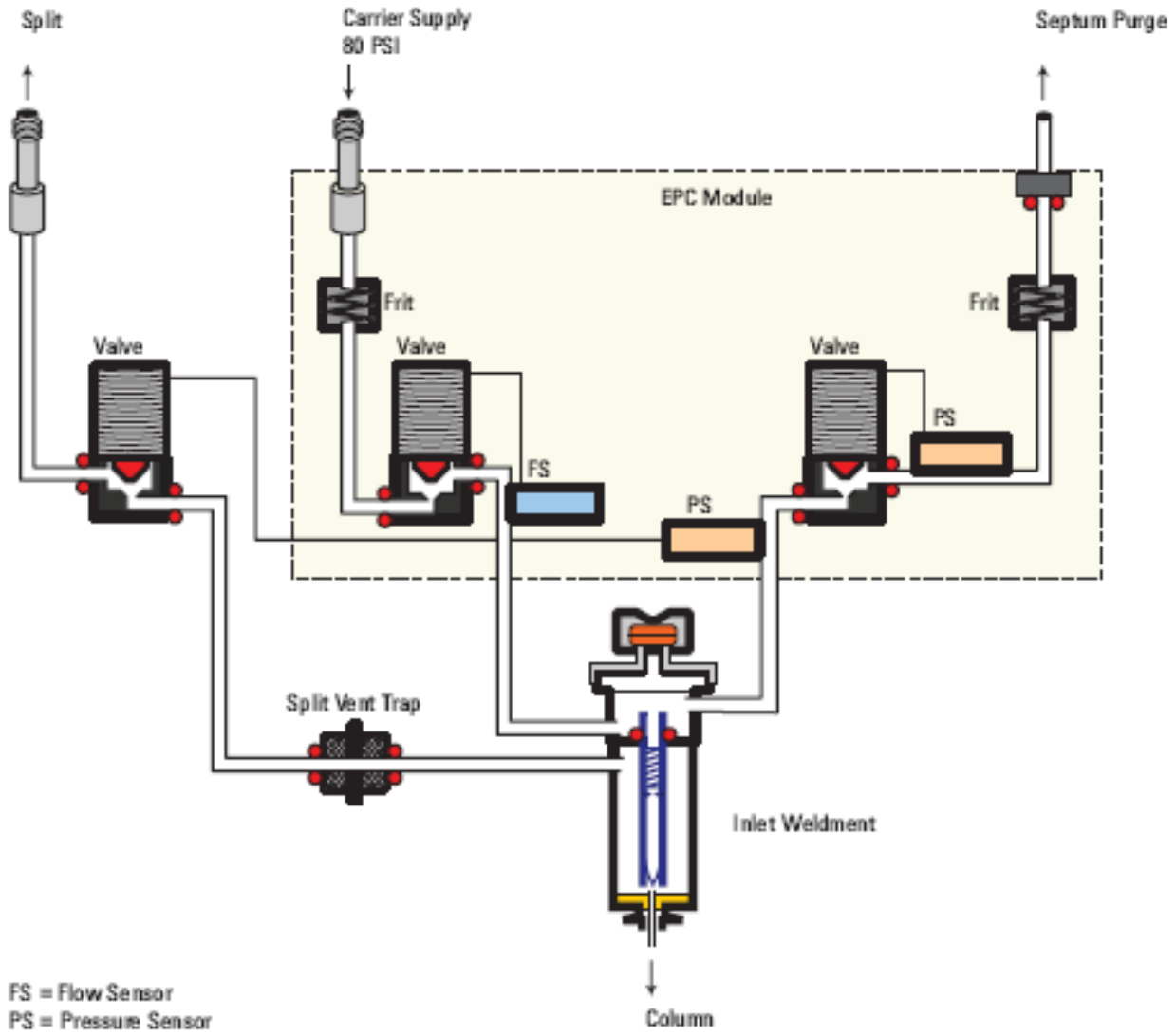
Same column, same chromatographic conditions

Inlet Choices

Inlet	Column	Mode	Sample Concentration	Comments	Sample to Column
Split / Splitless	Capillary	Split Purged Split Splitless Purged Splitless	High High Low Low	Most commonly used inlet. Very Flexible	Very Little Very Little All All
Multi-Mode	Capillary	Split Pulsed Split Splitless Pulsed Splitless Solvent Vent	High High Low Low Low	Flexibility of standard S/SL inlet and PTV	Very Little Very Little All All Most
Cool-On-Column	Capillary	N/A	Low or labile	Minimal discrimination and decompositoin	All
Packed	Packed Large Capillary	N/A N/A	Any Any	OK if resolution is not critical	All All
Programmed Temperature Vaporizaton	Capillary	Split Pulsed Split Splitless Pulsed Splitless Solvent Vent	High High Low Low Low	Not great for HOT injections. Can concentrate analytes and vent solvent	Very Little Very Little All All Most
Volatiles Interface	Capillary	Direct Split Splitless	Low High Low	Purge & Trap / Headspace	All Very Little All

Split/Splitless Inlet Schematic and Operation Modes

Modes
- Split
- Pulsed split
- Splitless
- Pulsed splitless



Split Injections - Considerations

Easiest injection mode to use

Excellent injection efficiency → Sharp peaks → Better resolution

Dirty Samples are less problematic (compared to splitless)

Solvent properties

- Wide boiling point range
- Wide polarity range

More prone to inlet discrimination especially at high split ratios

Need the Proper Liner

Split Injections - Inertness

More inert than splitless (apparent)

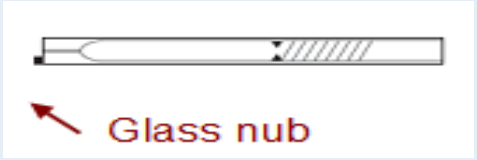
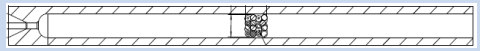
- Higher velocity through the inlet
- Less exposure time to inlet hardware/consumables
  - Therefore, less tailing/loss of response

Glass wool is a compromise

- Exhibits some activity – high surface area
- Greatly improves fluidic performance – mixing of the vaporized sample is important for uniform splitting
- Thermal mass/high surface area improves vaporization (less discrimination)
- Usually necessary in split

Inlet

Liners – split injection

Liner	Part Number Each 5/pk 25/pk	Comments
	5190-2294 (EA) 5190-3164 (5 pk) 5190-3168 (25 pk)	Simplest split liner, glass wool, UI deactivation, large volume (990 µL). Use for general purpose, can be used in splitless mode
	5190-2295 (EA) 5190-3165 (5 pk) 5190-3169 (25 pk)	Glass wool, UI deactivation, 870 µL volume. Glass nub ensures that a gap remains below liner for split injection. Efficient for most applications
	5190-5105 5190-5105-005 5190-5105-025	Sintered glass frit, UI deactivation. Ideal for basic drugs analysis. Sintered glass frit more reproducible than glass wool.
	18740-80190	Liner with Jennings cup, no wool. 800 µL volume. Reduces inlet discrimination.

Split Liners: Recommended Liner

Split/splitless liner with glass wool, low pressure drop

Split injections have higher carrier gas flow through liner

- Faster transfer onto column (excellent injection efficiency)
- Split liners have a smaller outer diameter than splitless liners to accommodate high flow to split vent

If potential exists for sample discrimination between low and high boiling components

- Use a liner with wool

Agilent Ultra Inert liners enable excellent peak shapes for tricky analytes

- 5190-2295 is recommended liner- Single taper, low pressure drop

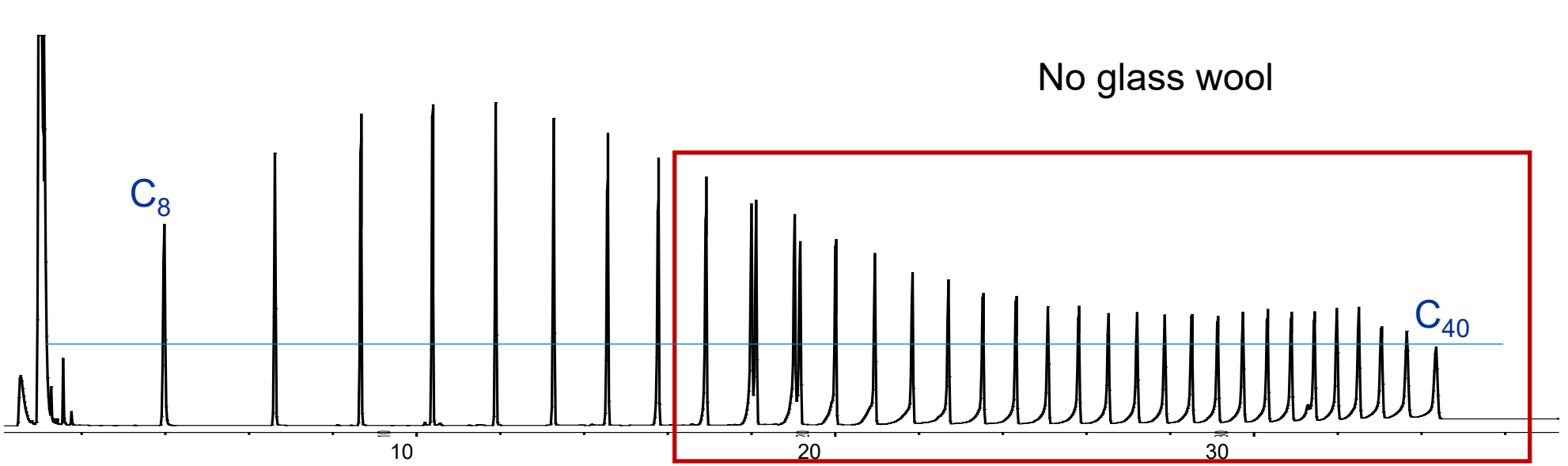
Touchless packaging ensures contamination-free installation

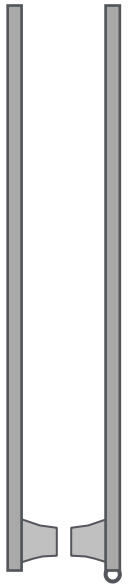
Preinstalled o-ring

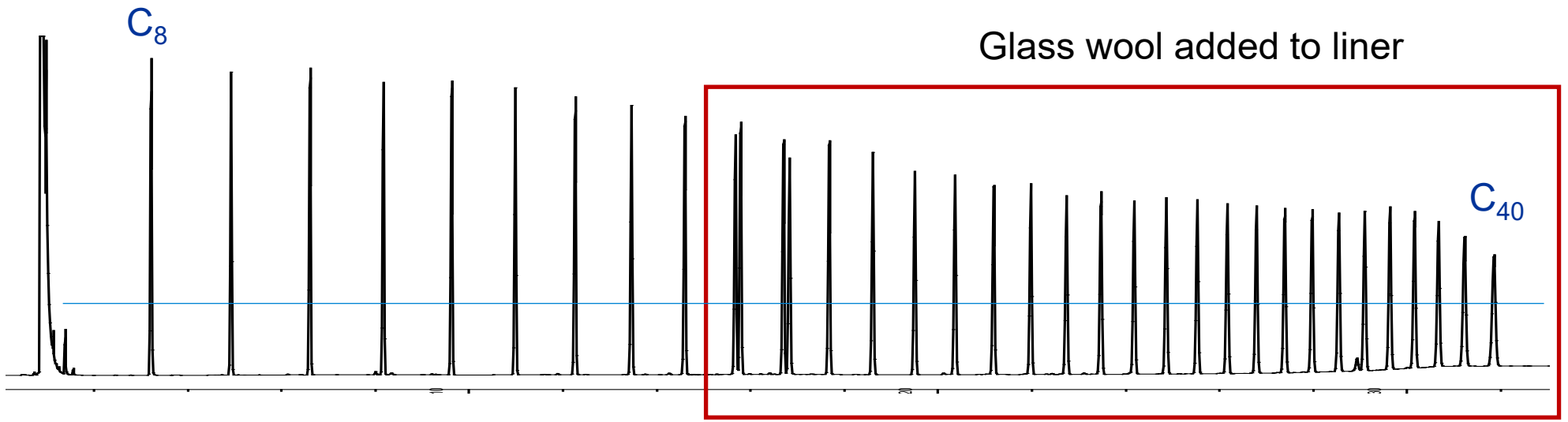
Glass wool plug in upper position wipes needle, avoids sample discrimination improves P&A, and collects septum particulate

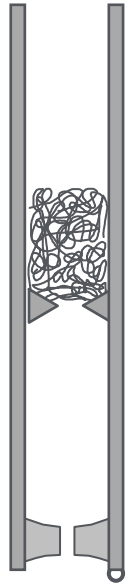
Low pressure drop bead promotes better carrier gas flow for split injections

What Does Inlet Discrimination Look like?









Split Injections - Maximizing Sensitivity

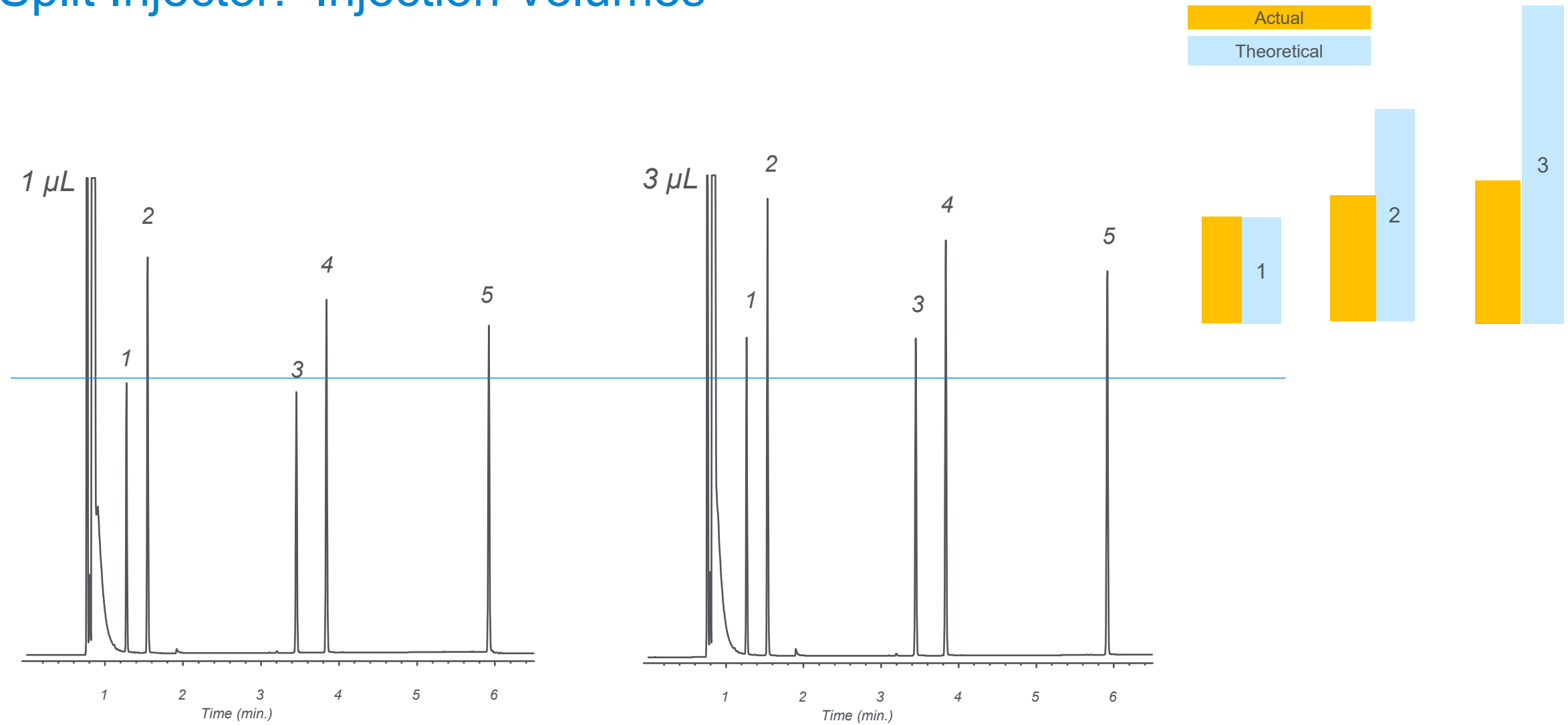
Reduce split ratio

- 10:1 practical lower limit for liquid injections (for 250 - 320 um i.d. columns)
- 1:1 possible for gas injections with larger diameter columns and correct liner
- Keep total inlet flow at 20 mL/min or higher

Increase Injection Volume

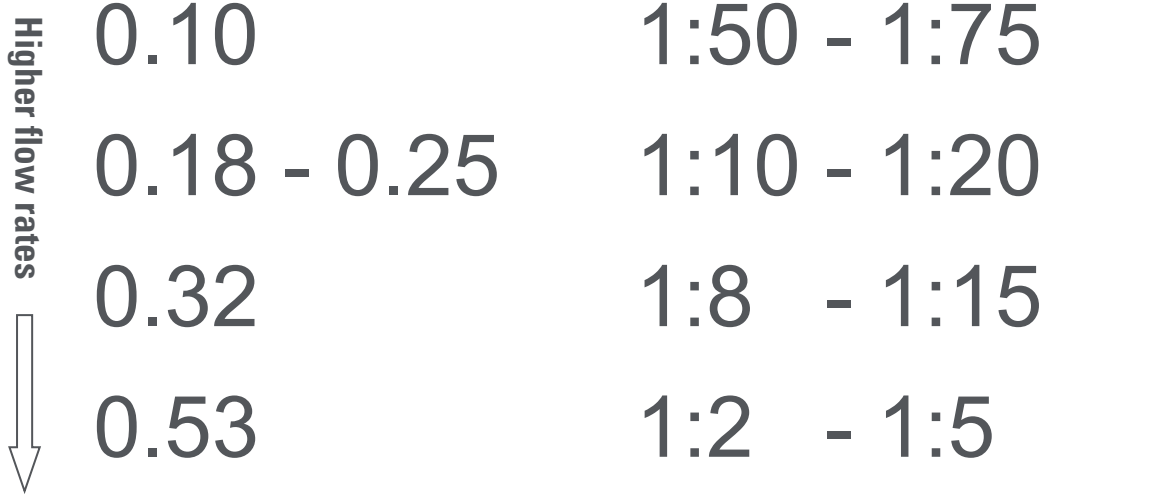
- Liner dependent (use the pressure-volume calculator; backflash)
- 2 uL maximum, but much more typical 1uL or less

Split Injector: Injection Volumes



Agilent J&W DB-1, 15 m x 0.25 mm I.D., 0.25 µm
60 °C for 1 min, 60-180 °C at 20 °C/min; Helium at 30 cm/sec
1. n-heptane 2. toluene 3. n-decane 4. n-butylbenzene 5. n-tridecane

Minimum Recommended Split Ratio*

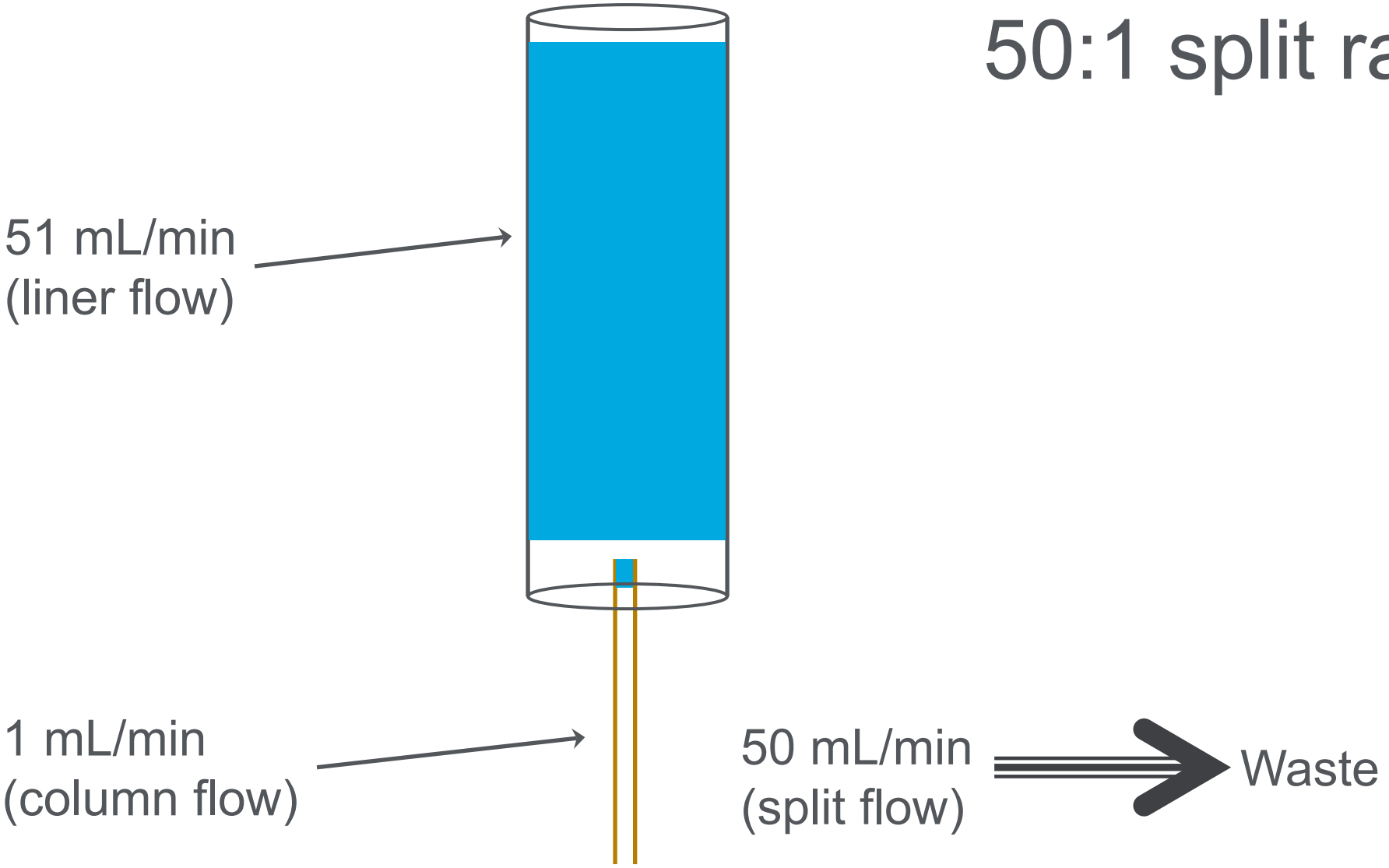


mm I.D.	Lowest ratio
0.10	1:50 - 1:75
0.18 - 0.25	1:10 - 1:20
0.32	1:8 - 1:15
0.53	1:2 - 1:5

*Most important to keep the TOTAL INLET FLOW ≥ ~20 ml/min

Split Injection

Animation



Splitless Injection Overview

- For trace level analysis
- Use split/splitless injection port in the splitless mode (split vent temporarily closed).
- The dilute sample is injected, the sample is volatilized, and majority of analytes transfer to the column
- Later (purge time), the split vent is opened, and remaining solvent is vented
- Timing, carrier and split vent flows, and oven temperature program are important
- Sample has longer residence time in the heated inlet giving more opportunity to vaporize high boiling sample components compared to split injection
  - Wool is less critical than in split
- Longer residence time in inlet will give more time for active compounds to interact with active sites (effectively making splitless less inert)

Splitless Injections - Considerations

Dirty samples are more problematic – essentially a quantitative transfer to the column

- Early eluters need larger bp difference vs solvent

Solvent Properties

- Need to consider bp of earliest eluting analyte
- Narrower Polarity Range –
  - More important to match stationary phase polarity to solvent polarity
- Greater sample residence time (actives)
  - Lower inlet temperatures can be used
    - Better for labile compounds

Solvent effect is usually necessary to re-focus solvent

Inlet

Liners – splitless injection

Liner	Part Number Each 5/pk 25/pk	Comments
	5190-2292 (EA) 5190-3162 (5 pk) 5190-3166 (25 pk)	Single taper, UI deactivated, 900 µL volume. Taper isolates sample form gold seal, reducing breakdown of active compounds. Trace samples, general applications.
	5190-2293 (EA) 5190-3163 (5 pk) 5190-3167 (25 pk)	Single taper, UI deactivated, glass wool, 900 µL volume. Glass wool aides with volatilization of heavier compounds and protects the column. Trace, dirty samples.
	5190-5112 5190-5112-005 190-5112-025	Singer taper, UI deactivated, sintered glass frit. Glass frit acts like glass wool but is more reproducible.
	5190-3983 (EA) 5190-4007 (5 pk)	Double taper, UI deactivated, 800 µL volume. Taper on inlet reduces backflash. High efficiency for trace, active samples.
	5190-7011 (5/pk) 5190-7012 (5/pk) 5190-7013 (5/pk) 5190-7014 (5/pk) 5190-7020 (5/pk)	Direct Connect liners, single and dual taper, original deactivation. Column press fits into liner. Focuses almost all sample onto column and reduces exposure to inlet. Ultimate for trace, active samples. Various hole placements for use with EPC

Splitless Liners

Single taper with or without wool

Splitless has lower flows through liner

- Splitless liners are typically wider for a more snug fit
  - ensures all available flow funnels through the liner, not around
- You can do split injections with a SPLIT liner as long as split ratio is not too high
  - Poor reproducibility, not enough room for high flows to the vent

Agilent Ultra Inert liners enable excellent peak shapes for tricky analytes

- 5190-2293 is recommended splitless liner- single taper, with wool

In low carrier gas flow splitless analysis, a **bottom taper** helps focus analytes onto head of column

Small plug of **glass wool** near bottom of liner filters matrix

Splitless Injections – Other considerations

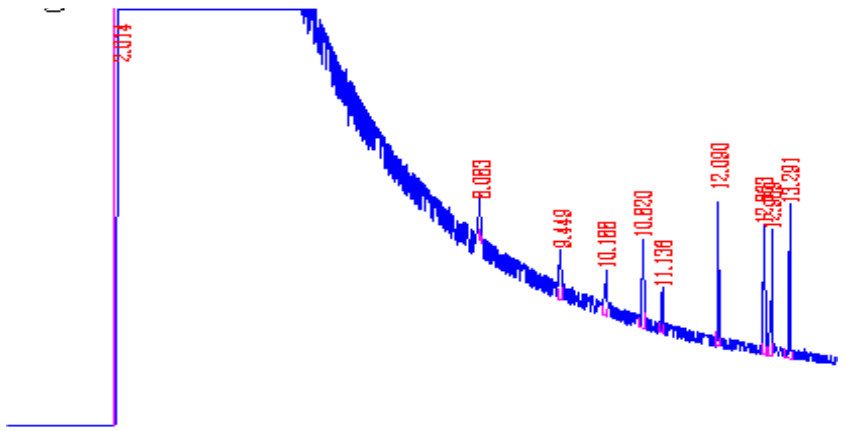
Improper purge time

- Short purge times cause loss of late eluters
  - Purge time of “zero” = pseudo split injection
- Long purge times cause solvent tail interference with early eluters

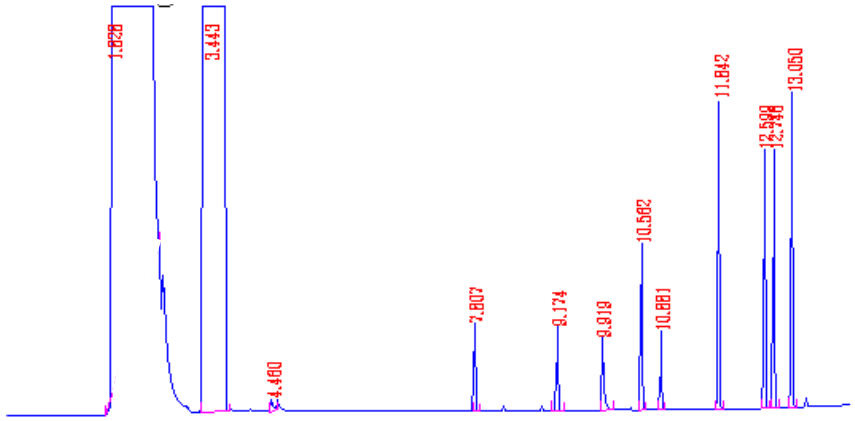
Improper initial oven temp (solvent effect - refocusing)

- Initial oven temp too high prevents solvent effect and a loss of early eluters

Splitless Injections – Splitless Time (Purge Time)

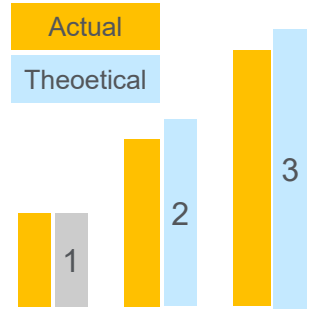


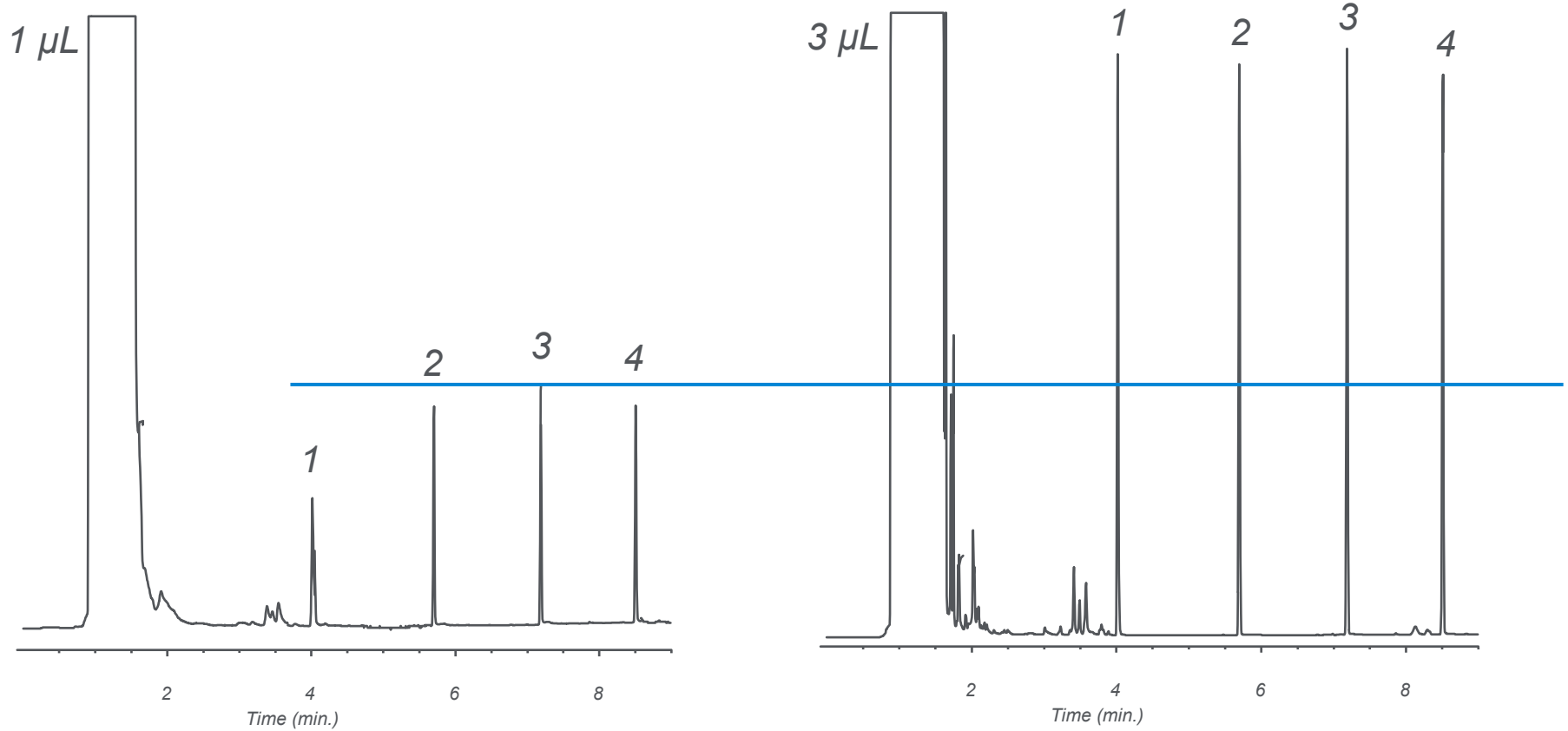
Purge time too long results in large solvent tail



0.75 min purge time clips solvent tail

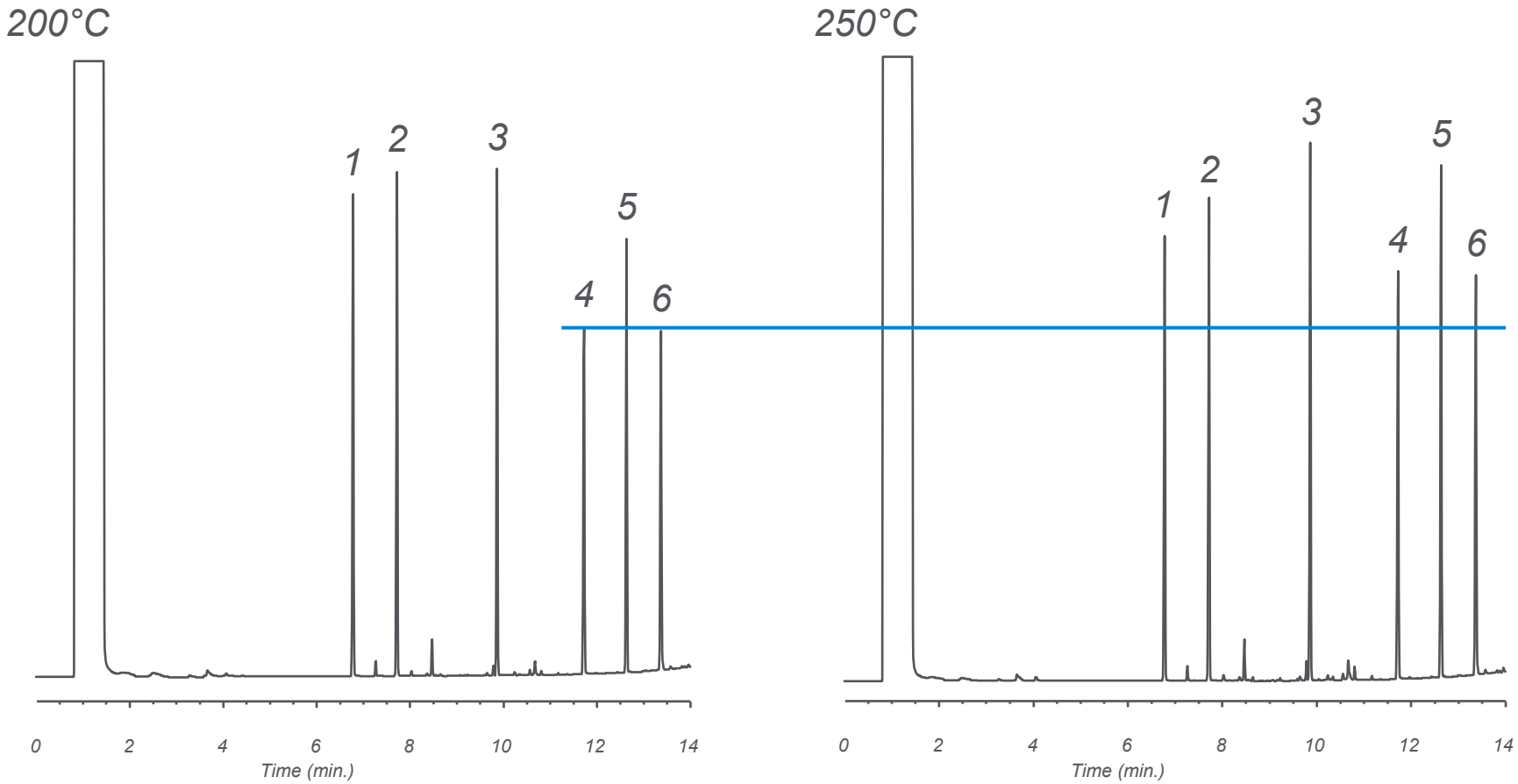
Splitless Injector: Injection Volume





Agilent J&W DB-1, 15 m x 0.25 mm I.D., 0.25 µm
60 °C for 1 min, 60-180 °C at 20 °C/min; Helium at 30 cm/sec
1. n-decane 2. n-dodecane 3. n-tetradecane 4. n-hexadecane

Splitless Injector: Injector Temperature



Agilent J&W DB-1, 15 m x 0.25 mm I.D., 0.25 µm
50 °C for 0.5 min, 50-325 °C at 20 °C/min; Helium at 30 cm/sec
Phthalates: 1. dimethyl 2. diethyl 3. dibutyl 4. benzylbutyl 5.bis(2-ethylhexyl) 6. dioctyl

Splitless: Sample Re-focusing and the “Solvent Effect”

- Splitless injections are inherently inefficient
- Sample refocusing
  - Also known as the “solvent effect”
  - Condenses sample as a thin film on the head of the column
  - Initial oven temperature must be at least 10 °C below the solvent B.P.
  - Increases separation efficiency and resolution and better peak shape
    - Especially for low boiling analytes

- “Cold trapping” is a version of sample re-focusing for high boiling analytes
  - Occurs when the starting oven temperature is ~150 °C below the boiling point of analytes of interest
  - Condenses the analytes on the head of the column
  - Results in better peak shapes

- Solvent effect and cold trapping can occur in same sample
  - When looking at analytes with a wide distribution of B.P.s

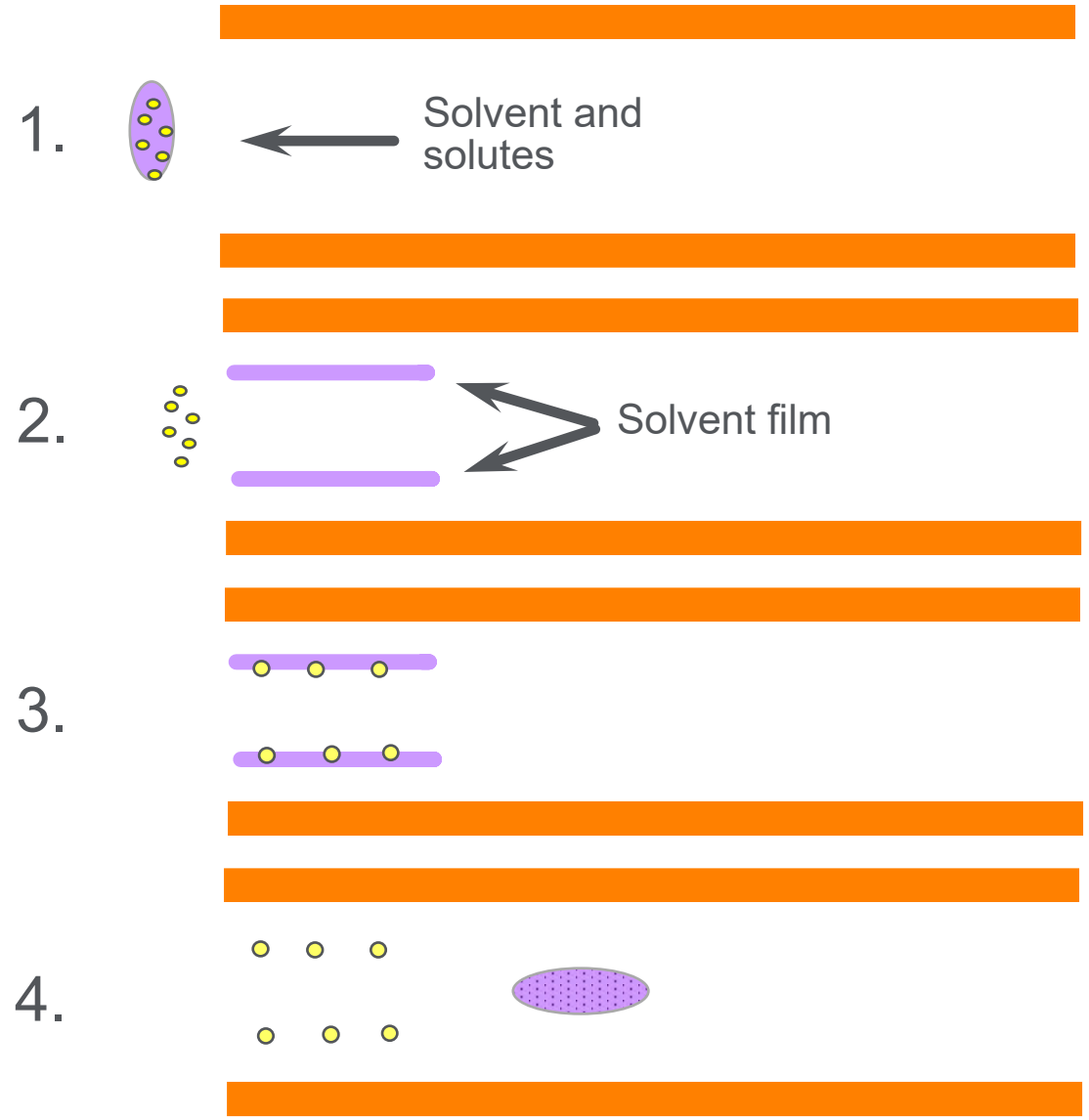
Splitless Injector: Solvent Effect

Initial column temperature at least ***10°C below*** sample solvent boiling point

Required to obtain good peak shapes unless cold trapping occurs (large Δ in BP)

Rule of thumb, if solute BP >150°C above initial column temperature, the solute will cold trap

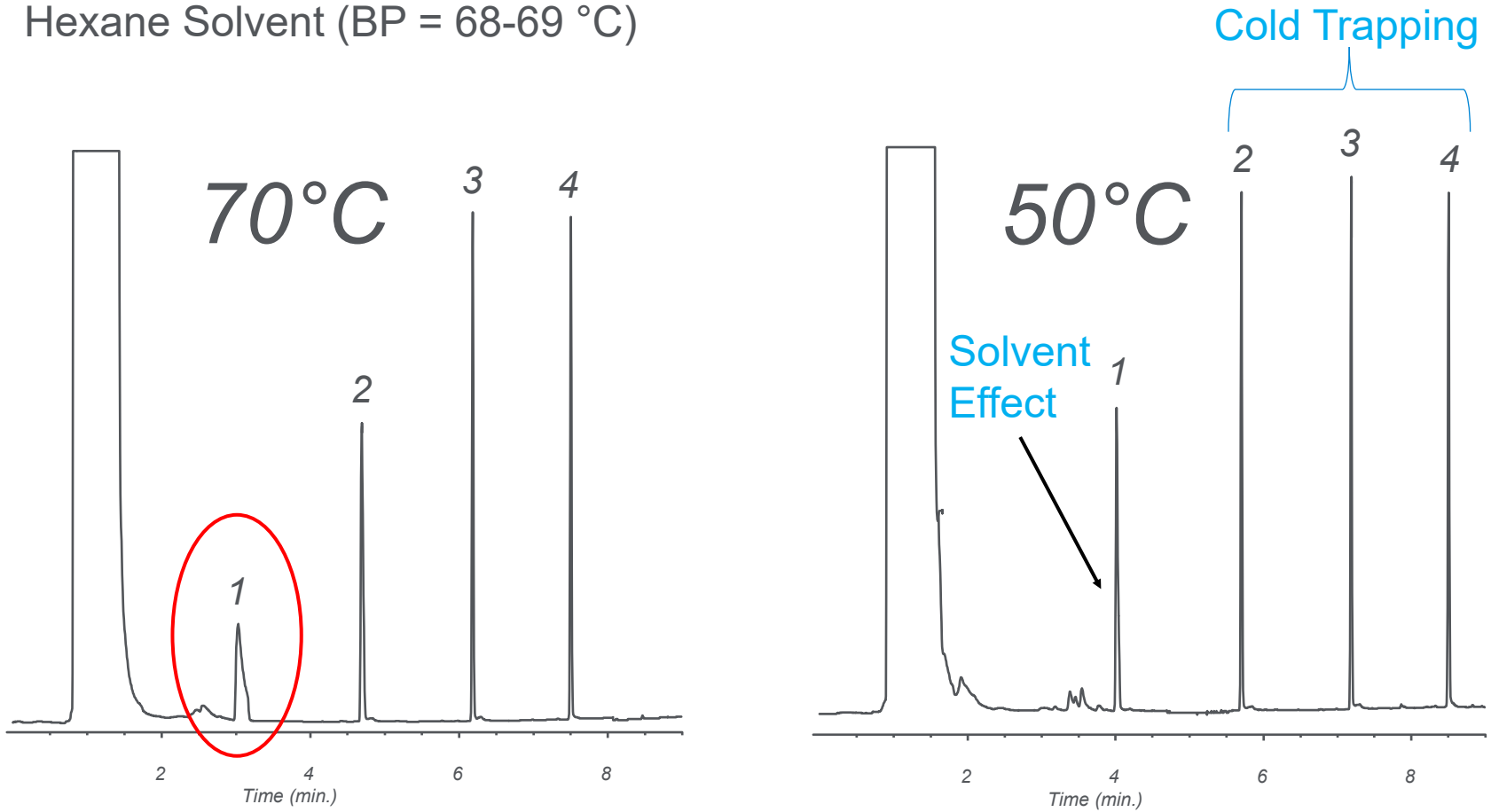
Cold trapping has greater efficiency than solvent effect



Splitless Injector

Initial Column Temperature

Hexane Solvent (BP = 68-69 °C)

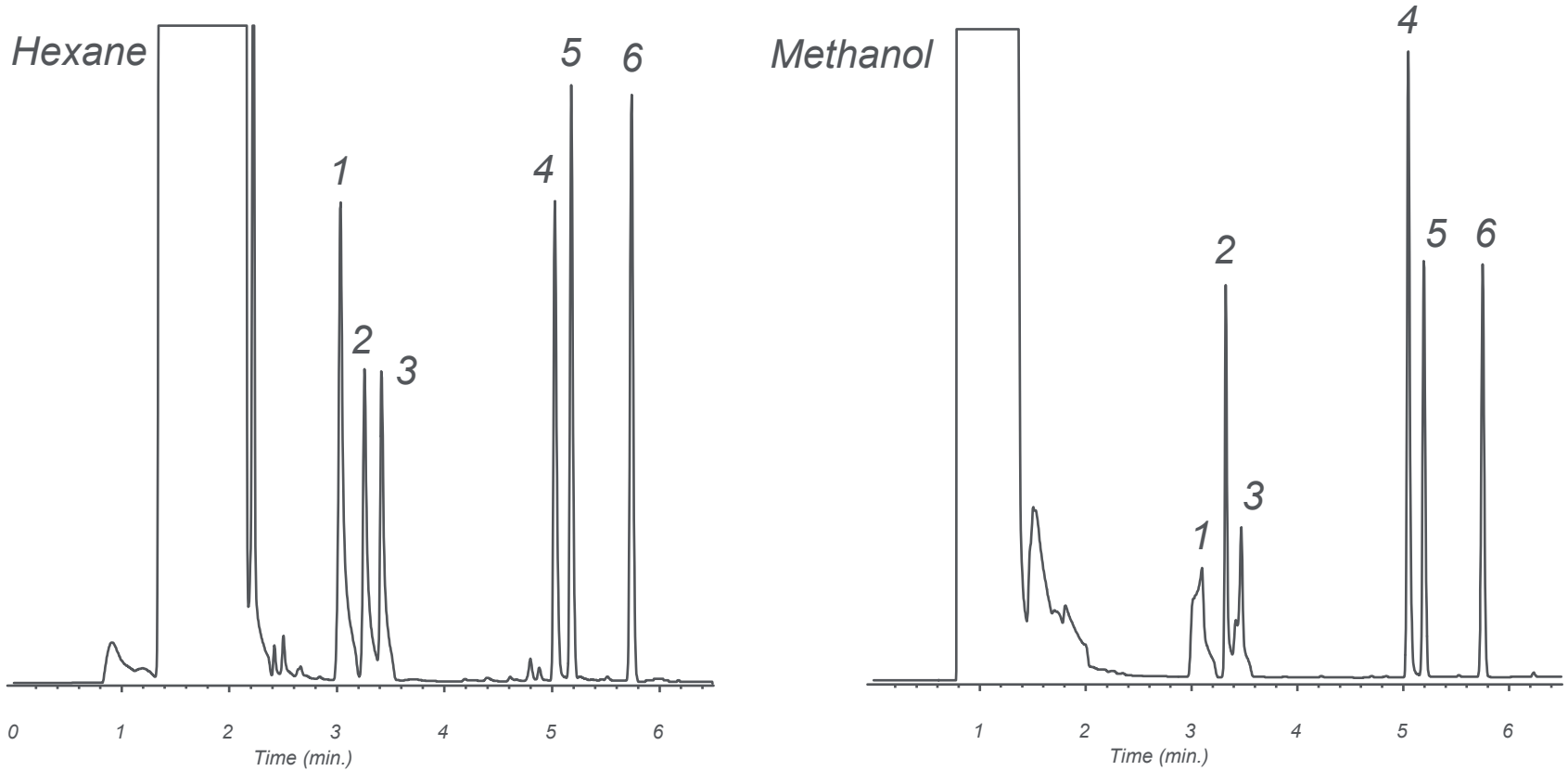


Agilent J&W DB-1, 15 m x 0.25 mm I.D., 0.25 µm
50 °C or 70 °C for 0.5 min, to 210 °C at 20 °C/min; Helium at 30 cm/sec
1. n-decane 2. n-dodecane 3. n-tetradecane 4. n-hexadecane

Splitless Injector

Polarity miss-match

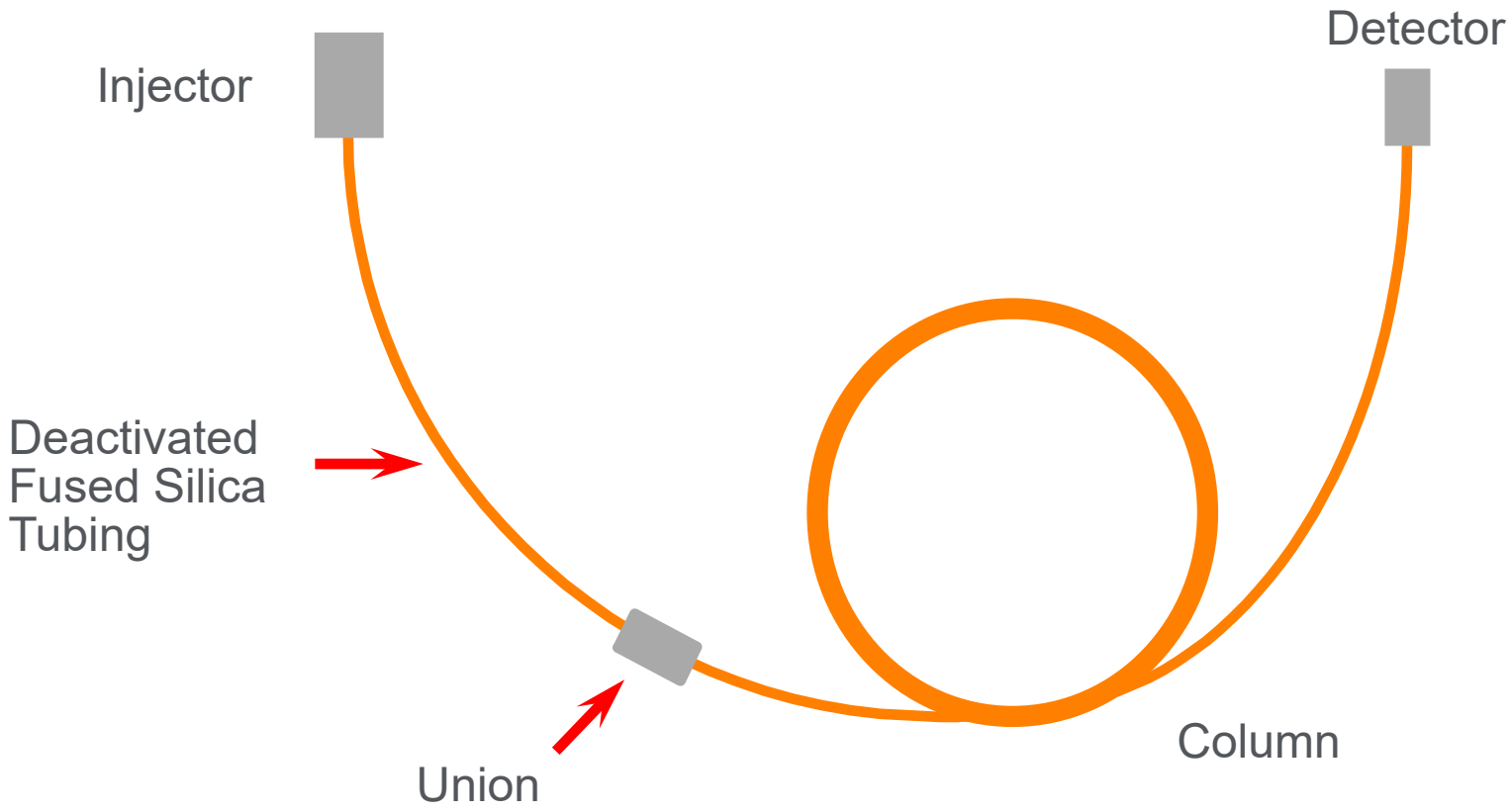
Agilent J&W DB-1



Agilent J&W DB-1, 15 m x 0.25 mm I.D., 0.25 µm
50 °C for 1 min, 50-210 °C at 20 C°/min; Helium at 30 cm/sec
1. 1,3-DCP 2. 3-hexanol 3. butyl acetate 4. 1-heptanol 5. 3-octanone 6. 1,2-dichlorobenzene

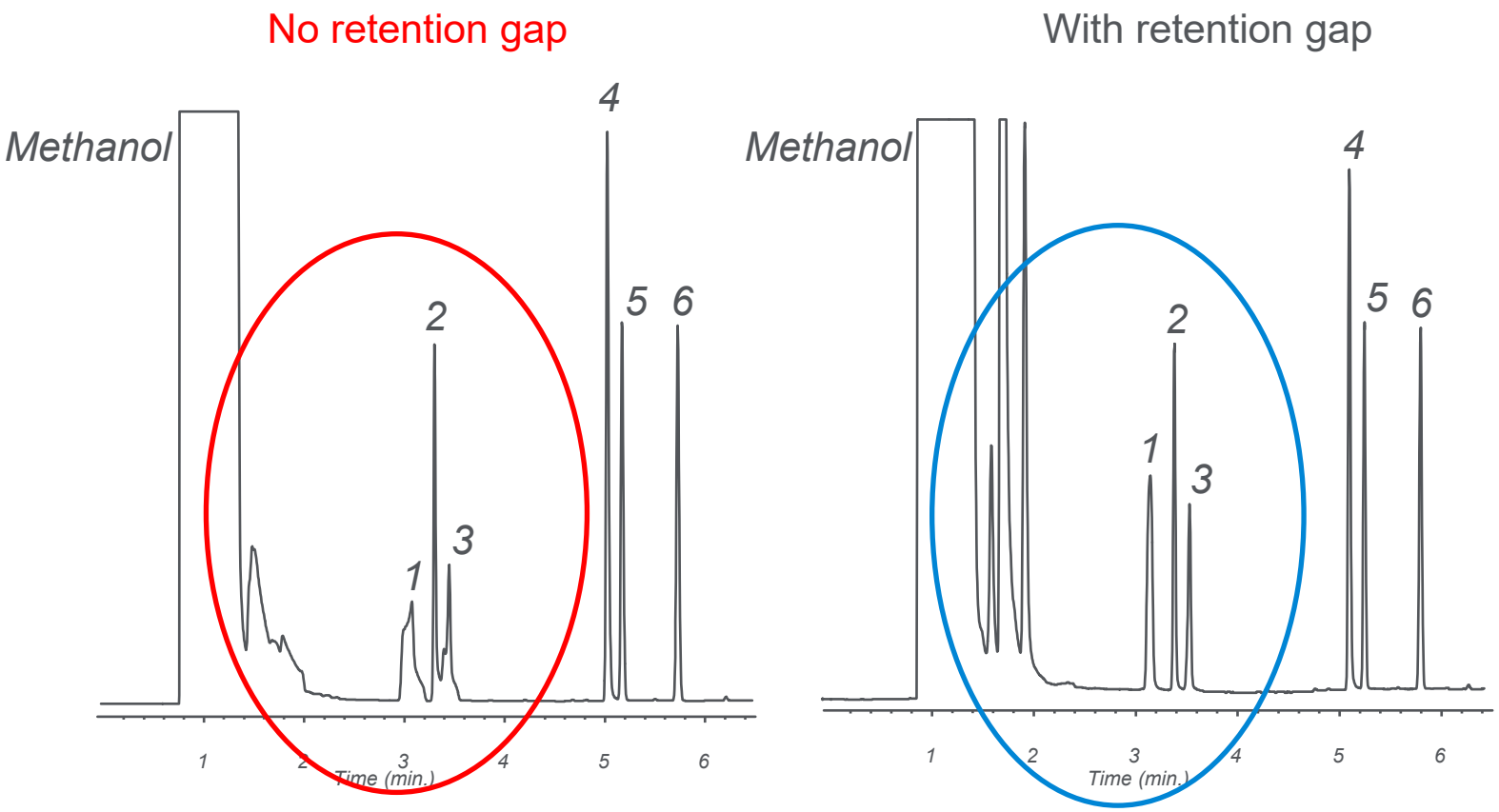
Retention Gap

Also called a guard column



Usually 2-10 meters long and same diameter as the column
(or larger if needed)

Splitless Injector
3 m x 0.25 mm I.D. Retention Gap



Agilent J&W DB-1, 15 m x 0.25 mm I.D., 0.25 µm
50 °C for 1 min, 50-210 °C at 20 °C/min; Helium at 30 cm/sec
1. 1,3-DCP 2. 3-hexanol 3. butyl acetate 4. 1-heptanol 5. 3-octanone 6. 1,2-dichlorobenzene

EPC for Pulsed Splitless Injection

Pressure pulse contains sample expansion and transfers analytes to the column faster

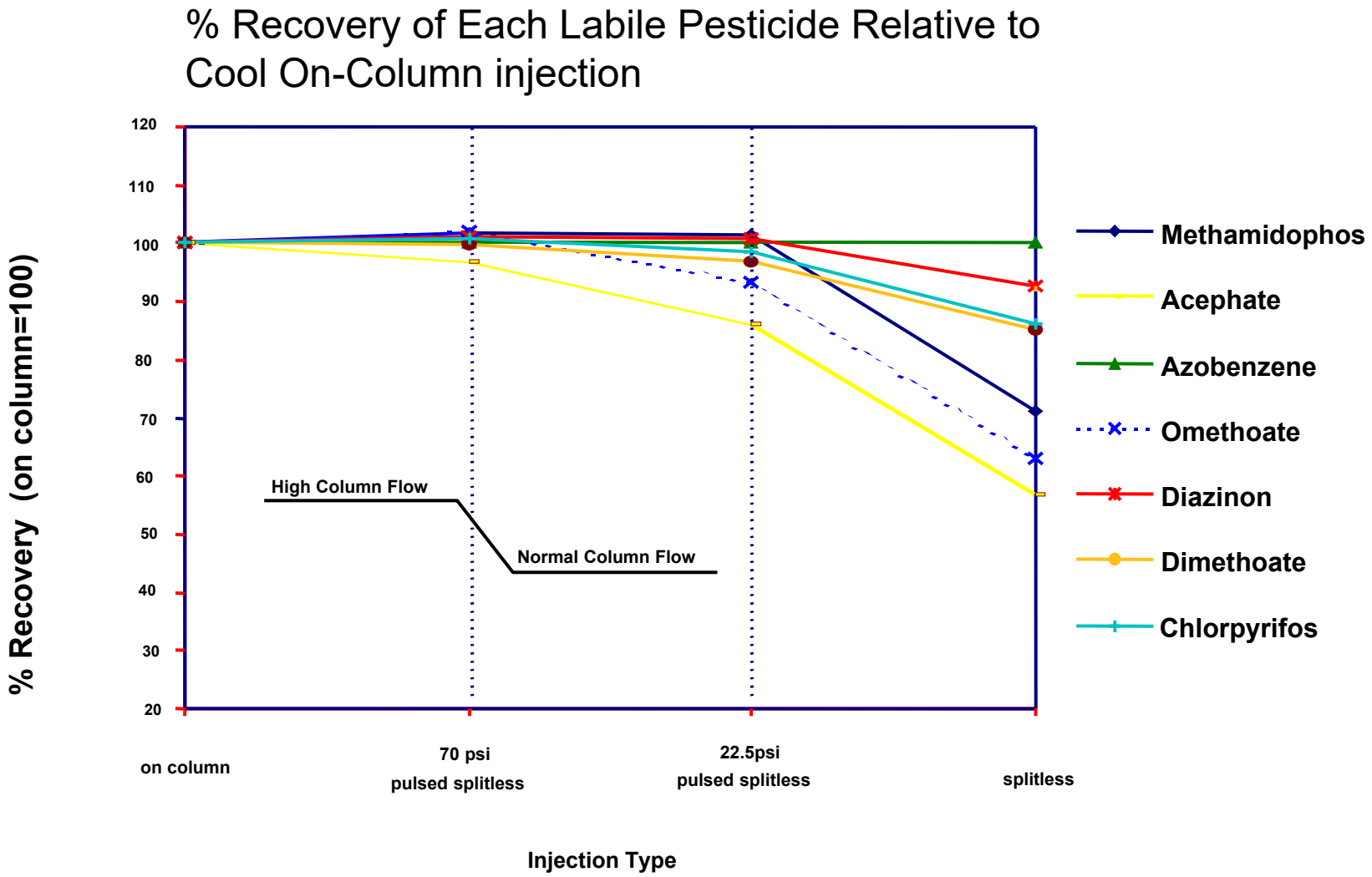
Pulsed splitless

- Sample containment more critical than in split injection
- Sharper peaks than in traditional splitless injection
- Two new parameters to set: pulse pressure and pulse time

Typical starting point

- Pulse pressure = double original pressure
- Tie pulse time to purge time
  - ***Purge time*** slightly shorter than ***pulse time***

Benefits of the Pulsed Splitless Mode – Actives Solutes



Splitless Injections – Starting Parameters

Injection volume = 1 uL

- Check the pressure-volume calculator

Initial oven temp = at least 10 ^{o}C < solvent boiling point

Purge flow = 50 mL/min

Purge time = 0.50 - 0.75 min

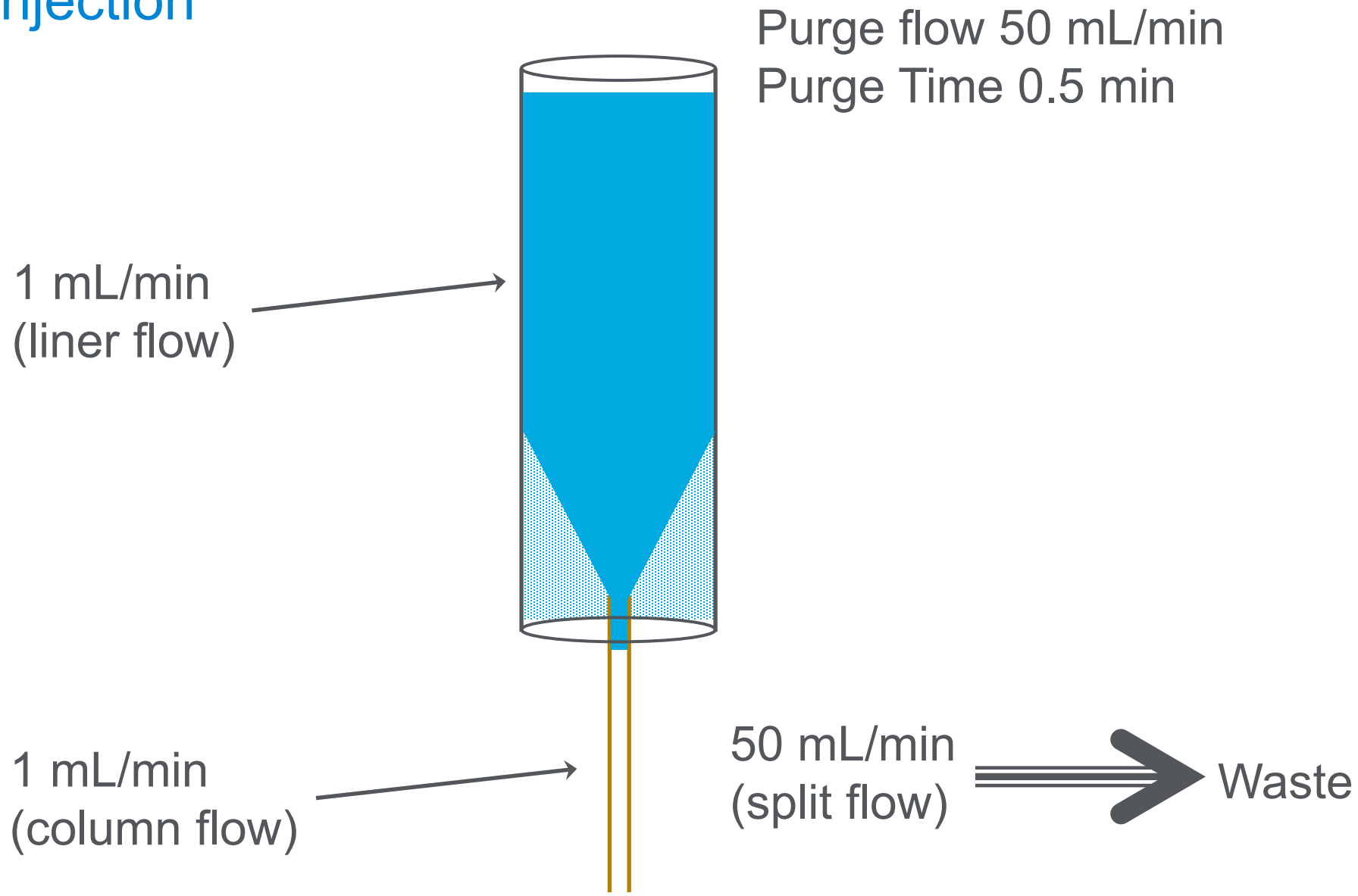
No pulse

Try to avoid water and methanol as solvents

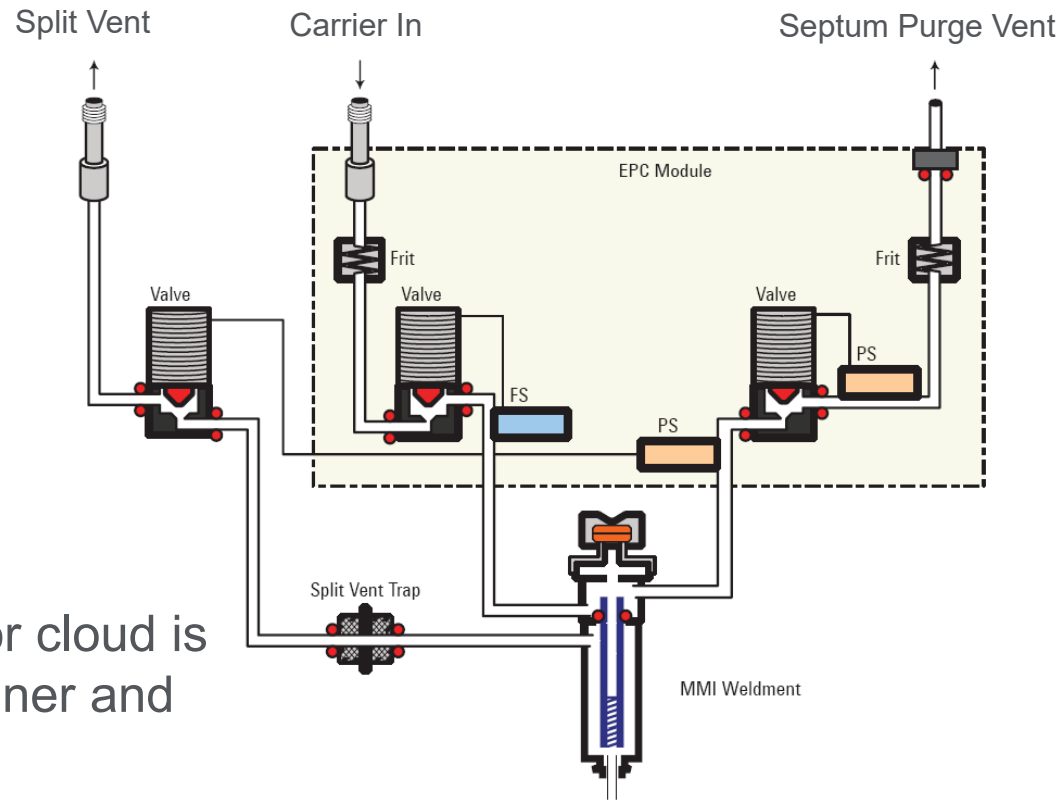
The goal is to maximize the response

Splitless Injection

Animation



MMI Inlet: Split/Splitless + PTV



Hot split/splitless (also pulsed)

- Similar/same as S/SL inlet using the **same liners**
- all previous S/SL discussions apply here

Cold split/splitless

Significantly more inert than hot splitless

- Can inject 3-5 uL with no solvent venting
- Better sensitivity than hot splitless because large vapor cloud is not formed instantaneously which travels outside the liner and portions are lost

LVI-Solvent vent

- An extension of cold splitless but uses solvent vent
- Large volume injection for maximum sensitivity

Direct mode

- Uses a direct connect liner – simulates COC (no purge)

Multi-Mode (MMI) Inlet Features

Temperature range of -160 °C to 450 °C

Heating @ 15 °C /sec (900 °C /min)

Septum/Liner Easily Exchangeable using Turn Top Inlet

Injection Modes: Hot S/SL, Cold S/SL, all in pulsed mode, solvent vent mode, residue removal mode

Support for single stroke injections from 0.1 µL to 250 µL

MultiMode Inlet Solves Many Problems

Performing large volume injection (LVI) of relatively clean samples

- Programmable injection slows solvent evaporation and maximizes analyte transfer into the column/detector
- Decrease MDL by injecting more sample

Injecting dirty samples

- Matrix vent, backflush and easy liner changing minimize dirty sample affects

Performing analyses of high molec. wt. and/or thermally labile compounds

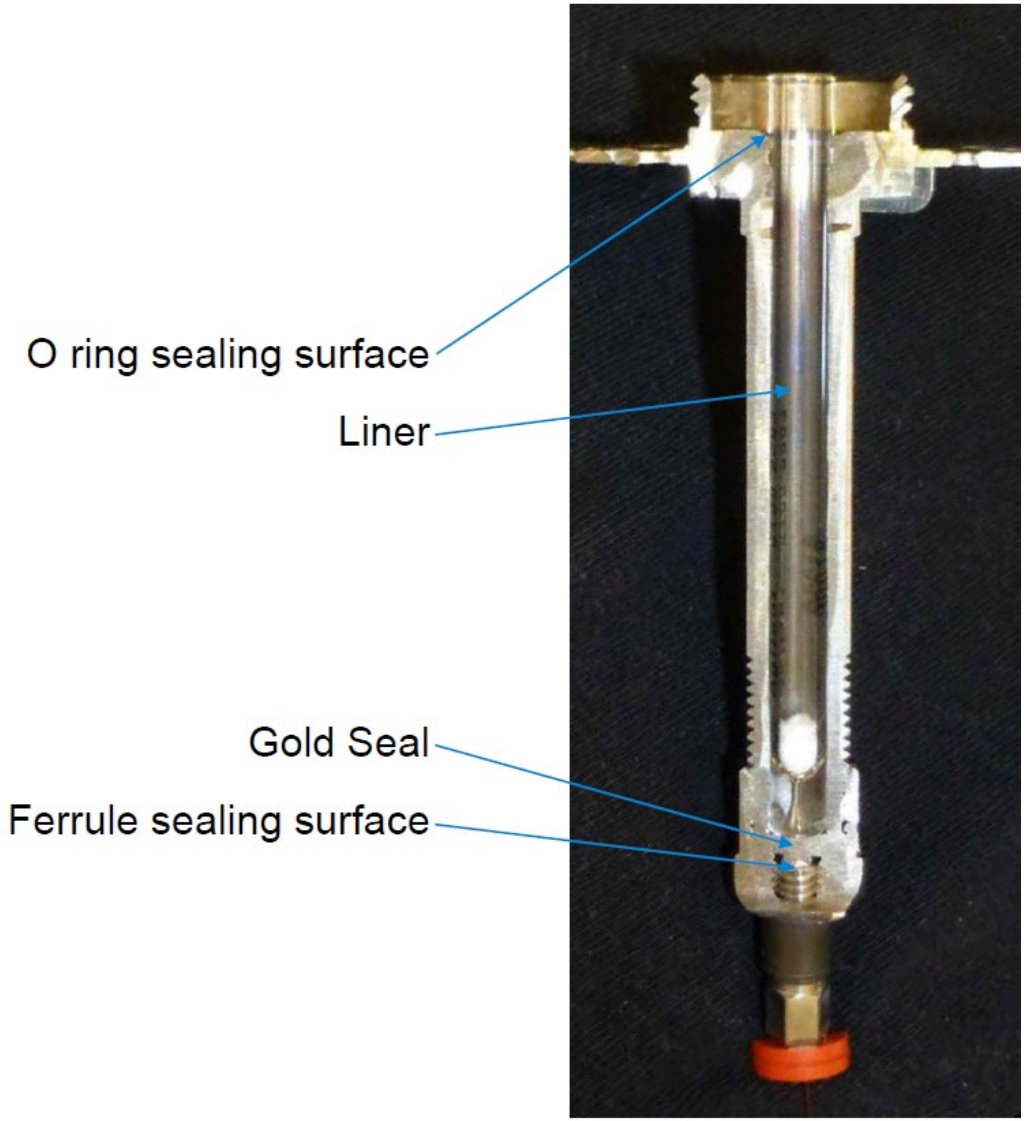
- Temperature programming of Multimode inlet elutes analytes at the lowest possible temperature, minimizing breakdown and absorption
- Discrimination of high molec. wt. compounds is minimal allowing HT GC

MultiMode GC Inlet - Cold Injections

- No syringe-needle discrimination; Minimal inlet discrimination
- No special syringes, liners or consumables
- Solvent vent/matrix vent - decrease interference / maintenance
- Flexibility (hot/cold split/splitless, temperature programmed vaporization)
- Cold trapping in liner - improves chromatographic peak shape, resolution
- Capillary column backflush with CFT - decreases cycle time, maintenance
- Large volume injection (5ul to 250ul) - lower detection limits
  - **Sensitivity is better *but also introduces that much more matrix*!**

Inlet Degradation and Maintenance

Root Causes of Inlet Performance Degradation, and Consequences



Accumulation of Sample Residues on “front-end”

- Loss of response, tailing on active analytes, split vent trap fouling and inaccurate EPC flow control

Accumulation of Consumables wear particles

- Same as Accumulation of Sample Residues, plus “bleed peaks”

Leak in Septum Nut, Septum

- Damage to O_2 sensitive detectors, irreversible damage to column

Non-Optimized Set-up

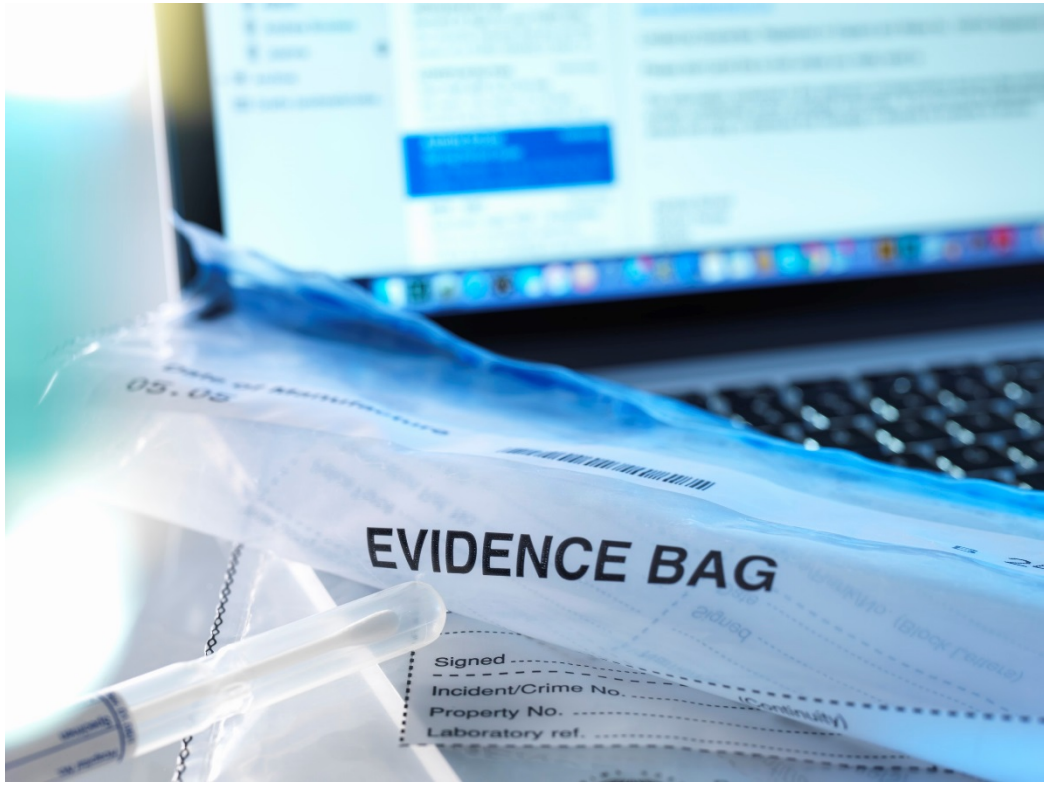
- O-ring, Gold Seal, Ferrules, Column Nuts
- Faster inlet performance degradation between maintenance sessions

Troubleshooting – “Front-End”

- Many chromatographic problems are blamed on the column.
- Often, a dirty liner/front-end is the culprit.

Evidence of Front-end contamination:

- Poor peak shape
- Irregular baselines
- Poor resolution
- Poor response
- RT Shifts
- Bonus peaks
- A dirty liner! ☺



Splitless Liner Maintenance

- Liners become contaminated with use, collecting non-volatiles, salts, excess reagents, etc., or become damaged/cracked.
- Should inspect and replace liners often.
- Handle with gloves and forceps.
- Insert into or remove liners only from cool injection ports.
- Replacing with a new liner is recommended, to ensure reproducibility

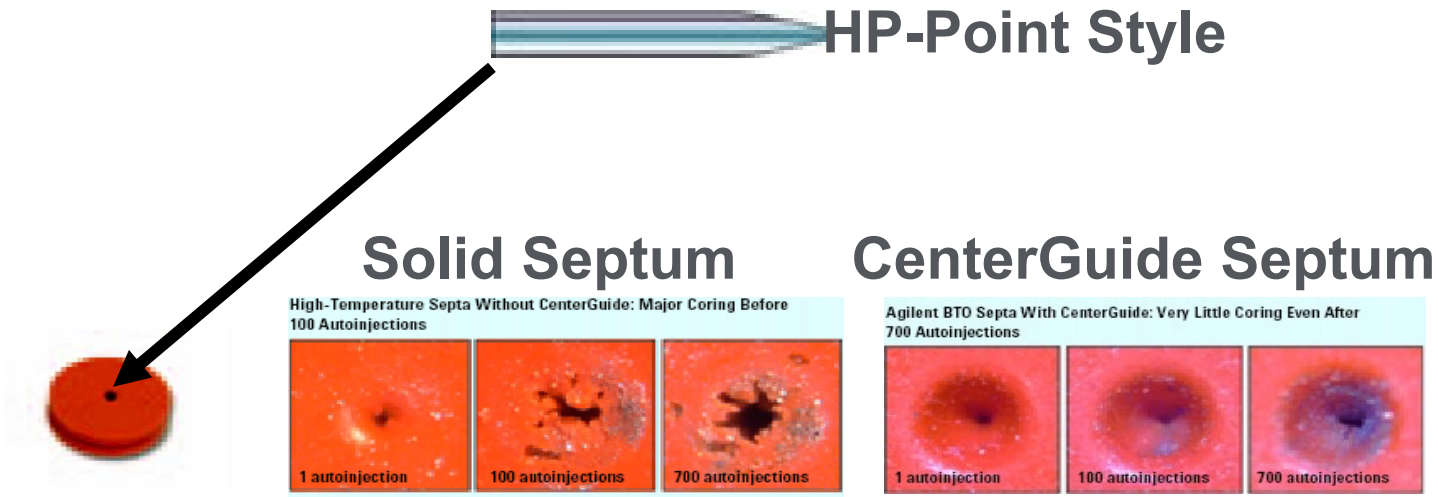
Leak in Septum

Using septa beyond lifetime/temperature conditions

- “Use environments” that decrease lifetime include manual injections, wrong syringe tip type, larger gauge syringes, non-Agilent Autosamplers (Agilent’s are precisely aligned)
- Septum nut too tight
- Septum type and syringe needle type mating are essential to minimizing leak rate
- Typical cost of 1 premium septa ($1.25)
- Typical cost of 1 GC column ($600)
- Proactively change inlet septa

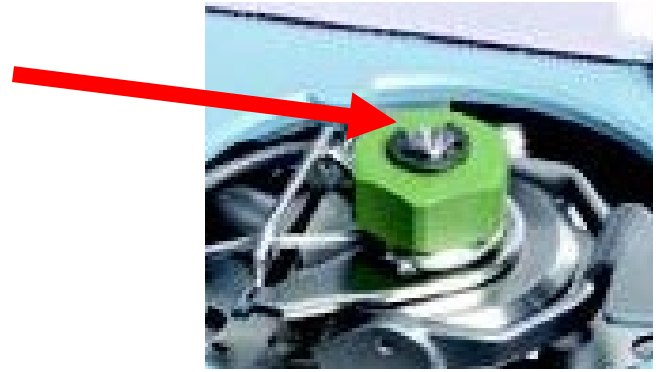
Tips to Maximize Septum Life, Minimize Septum Leaks

- Use Agilent Gold Standard, 23-26 gauge, HP point taper syringes
  - Point style cores septa significantly less when used with CenterGuide Septa
  - Taper minimizes septum coring/wear
- Use Agilent CenterGuide Septa
  - Molded hole minimizes septa coring



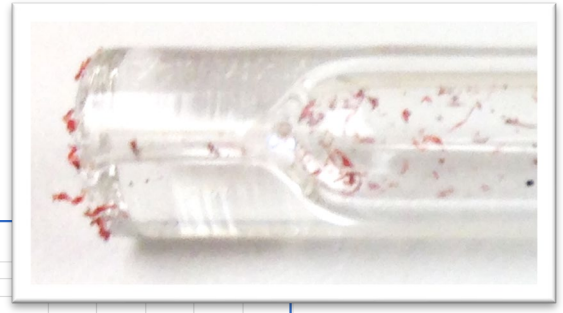
Leaks Due to Septum Nut

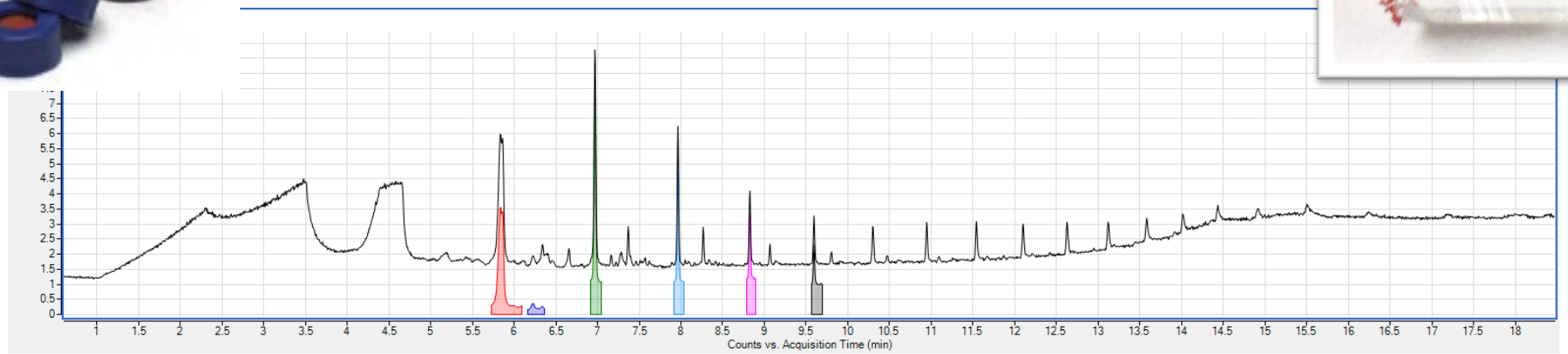
- With repeated use, conical needle guide gets worn, out of round, and needs replacement as septum can begin to “bulge” out, especially with excessive tightening
- Septa fail faster because needle is not guided with as much precision
- Under or over tightening—tighten nut until c-clamp on top stops turning, C-clip should rise above green nut resulting in ~1 mm gap
- Non-Agilent septa may be too thin, too thick, or out of round like die-cut septa and may not seal as well
- “Use Environments” that decrease lifetime, like using non-Agilent autosamplers (ours are precisely aligned), manual injection, larger gauge syringes
- Replace septum nut annually for peace of mind

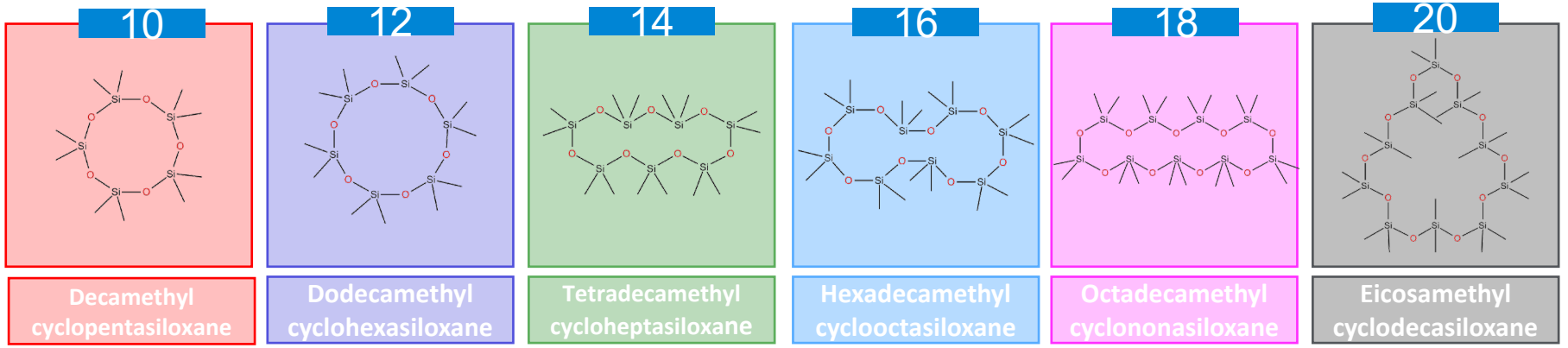


Main Siloxane Peak Bandit!!!

Multiple injections from same vial can dissolve silicone into the sample

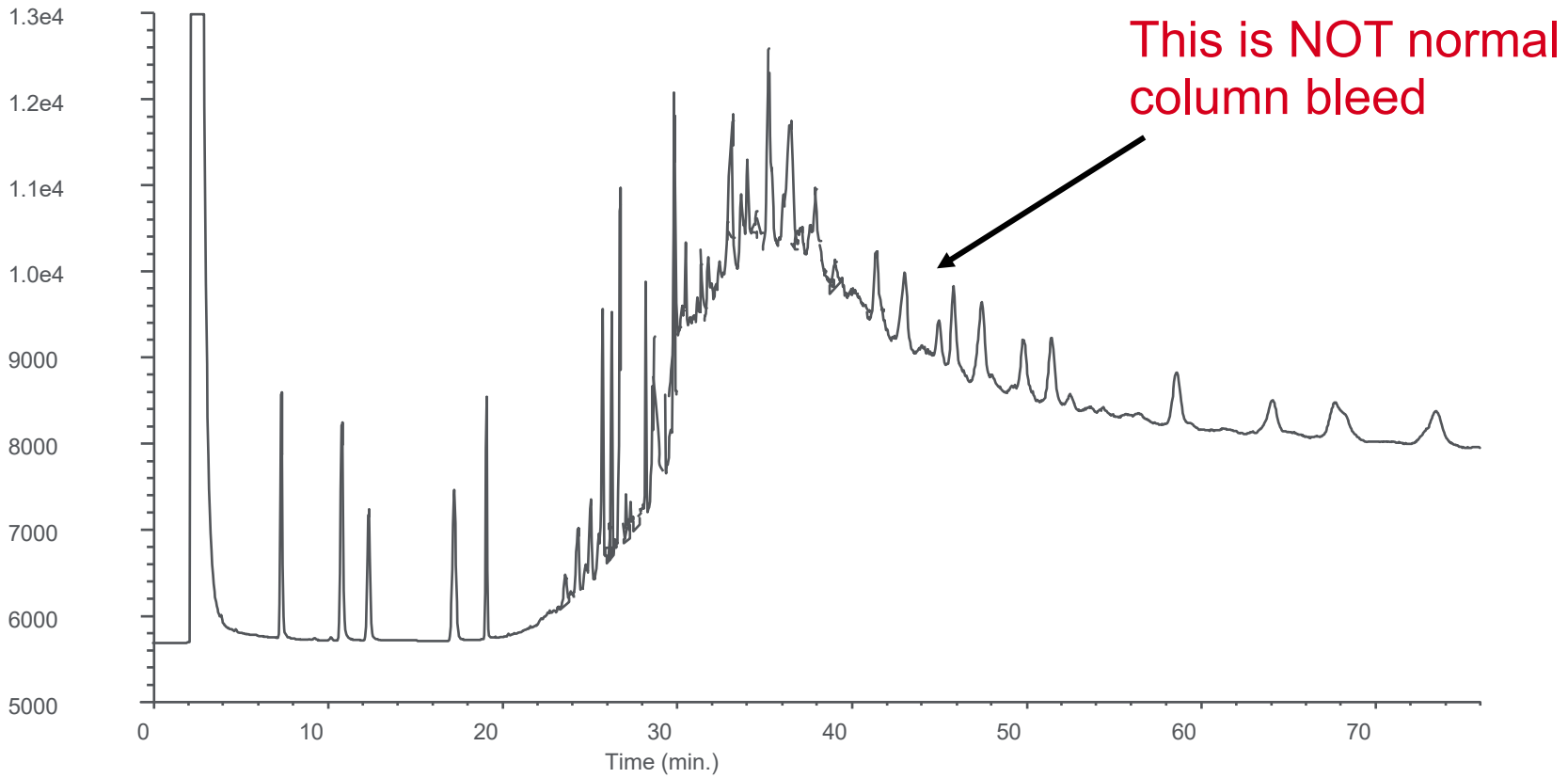






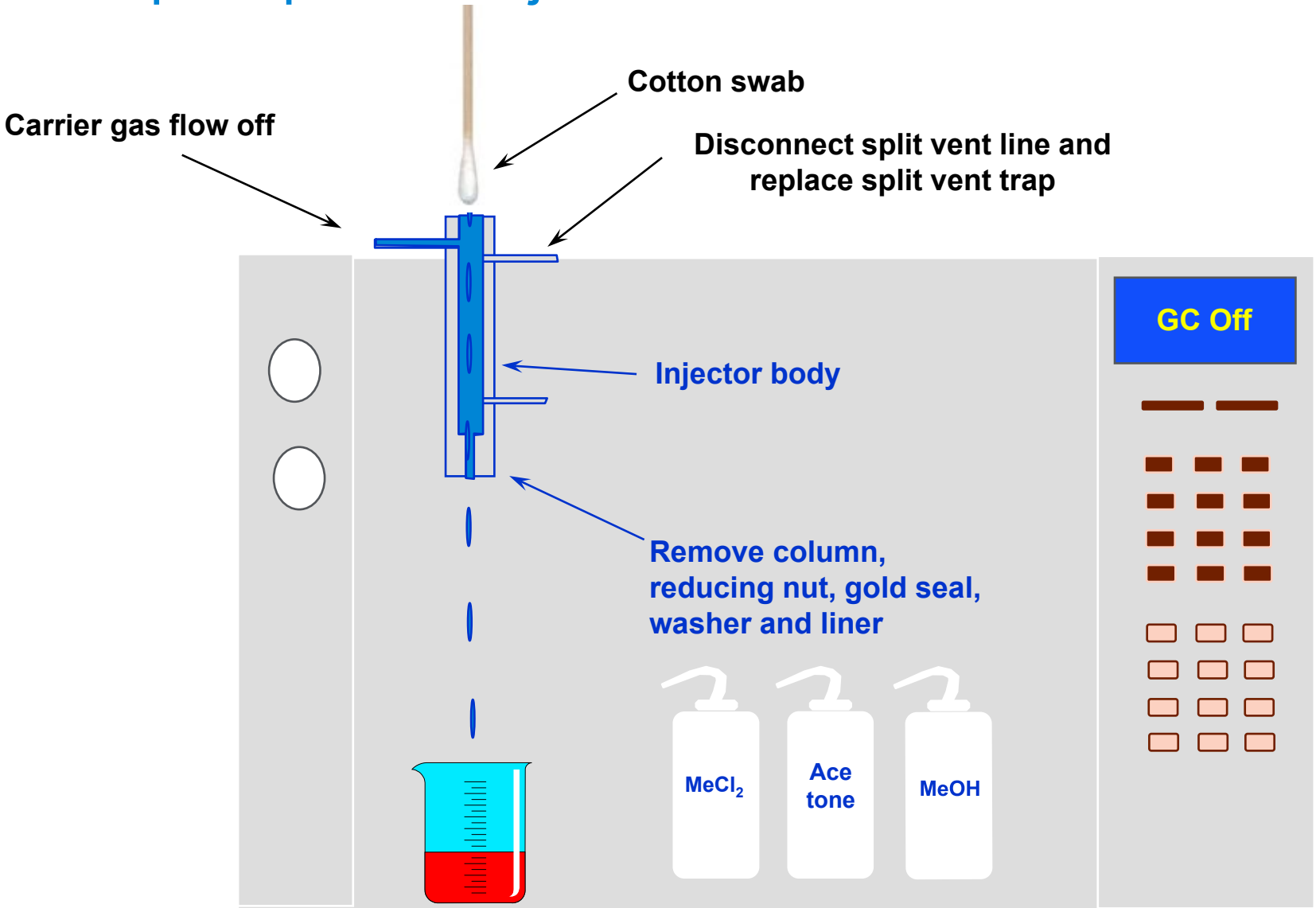
Agilent

Example Of Gross Contamination



Agilent J&W DB-624, 30 meter megabore
Temperature program // 35 °C, hold 1.50 min // 30 °C/min to 65 °C, hold 15 min // 20 °C/min to 260 °C, hold 50 min

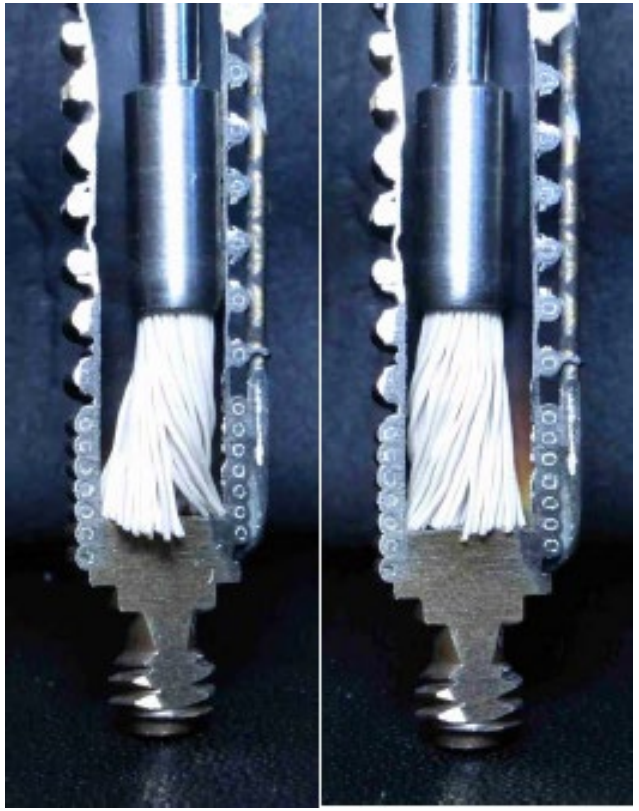
Cleaning the Split/Splitless Injector



Cleaning the MMI Injector

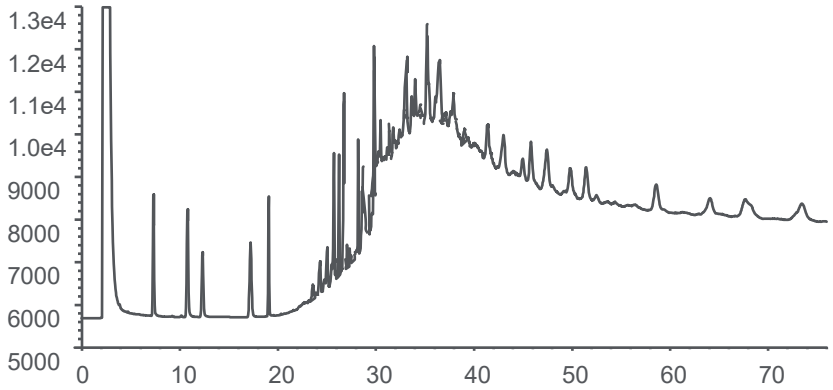
The gold seal at the bottom of a Split/Splitless port can be replaced, but not on the MMI. The same areas need to be cleaned, though. Agilent sells an MMI cleaning kit –G3510-60820 ~$38 USD. It includes an abrasive brush, shown, some swabs, and instructions. The cleaning kit manual is online at (G3510-90820.PDF)
https://www.agilent.com/cs/library/usermanuals/public/G3510-90820.PDF

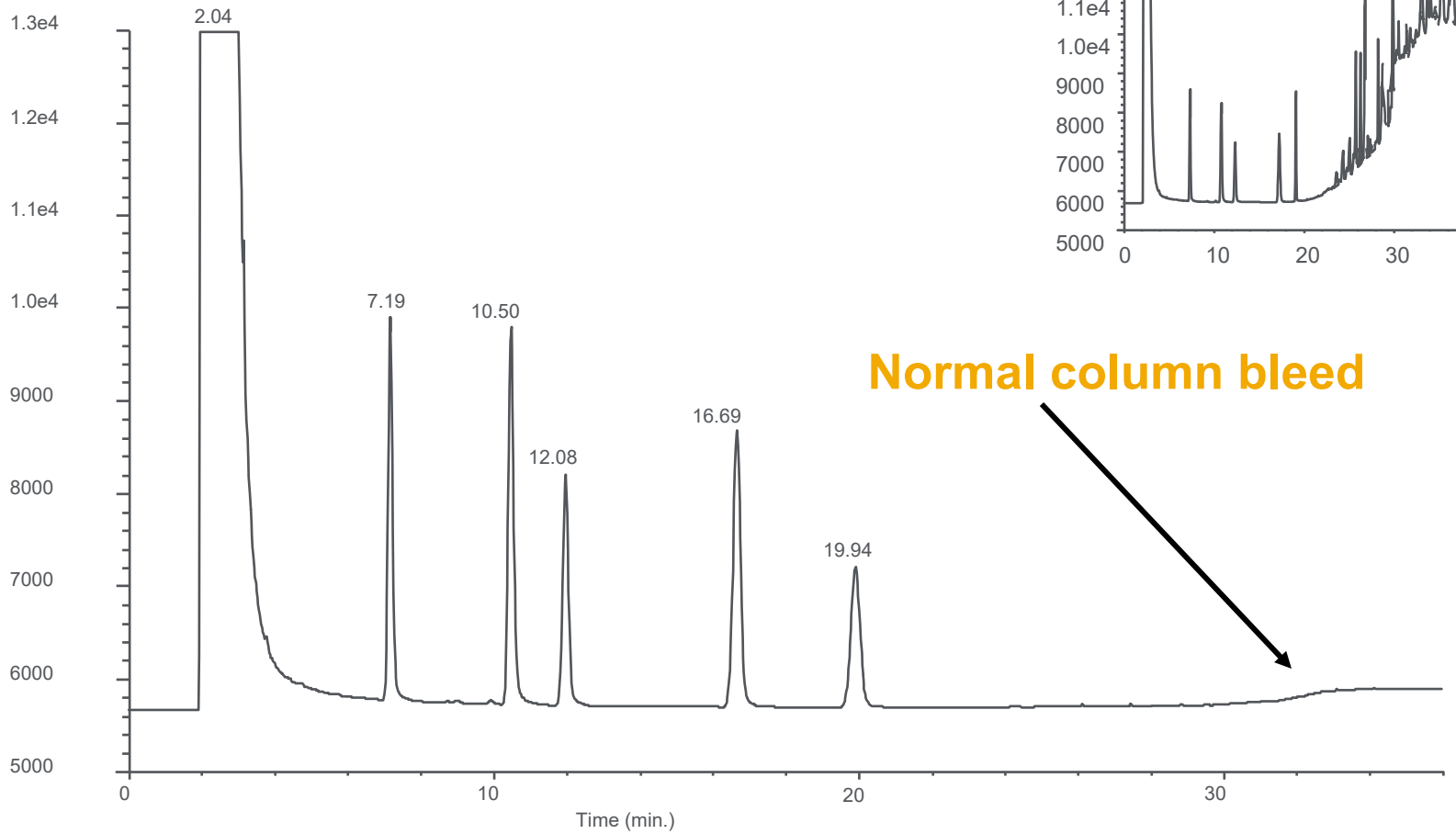
Procedure:
Start with the inlet cold, the liner removed, the column removed, a beaker in the oven to catch the rinse solvent, and safety glasses and gloves on.



1. Dampen the abrasive brush with clean acetone, methanol, or isopropanol.
2. Slide the abrasive brush into the port
3. Twist it to the left. Twist it to the right
4. Go back and forth a few times, pushing downwards with moderate pressure. Do NOT push down hard as the port could be damaged. Only press down enough to maintain firm contact between the brush and the bottom of the inlet and splay the bristles outward as shown.
5. Remove the brush and rinse it in clean solvent.
6. Repeat three to five times
7. Using clean solvent, rinse the inlet bore several times but never allow the liquid to fill more than half of the bore. You do not want solvent to go into the split vent line.

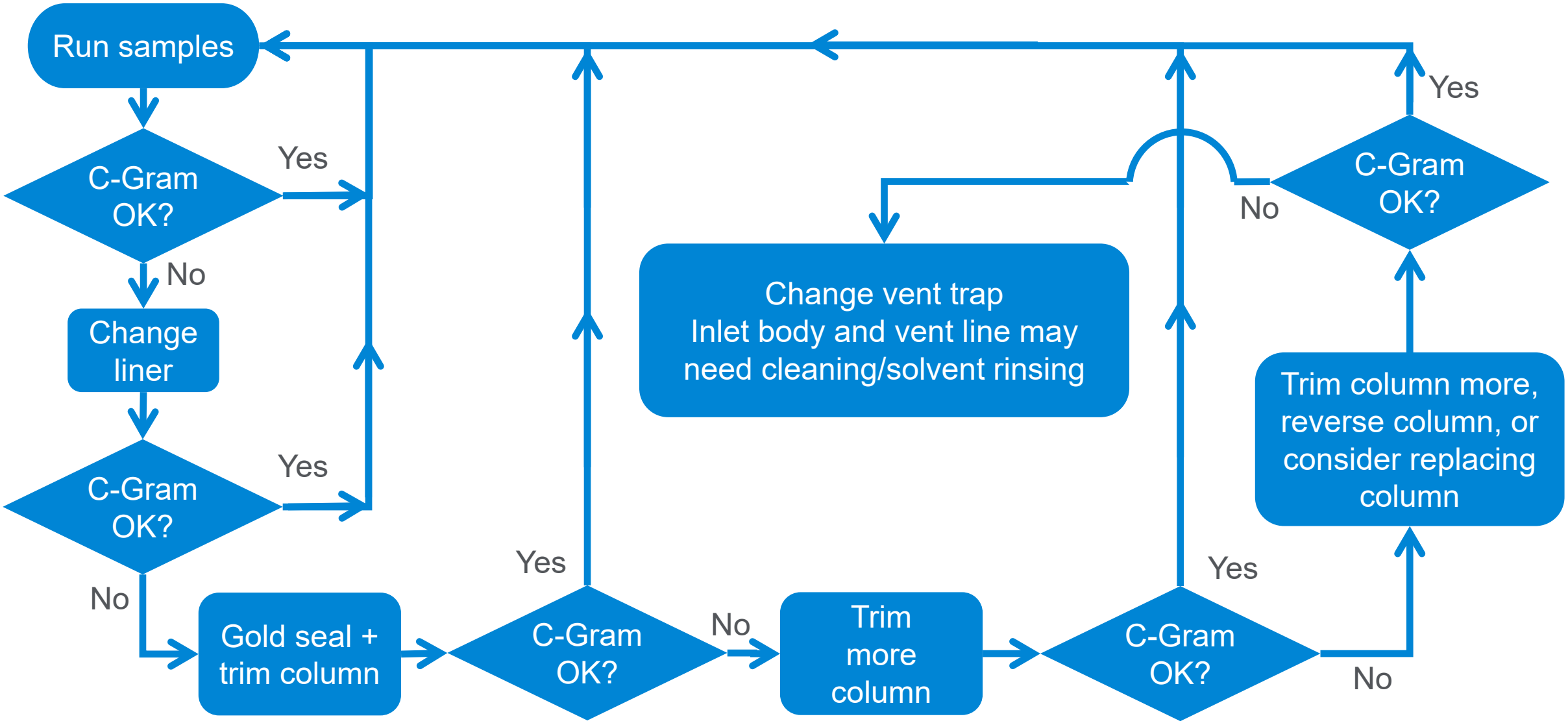
Same Column After Inlet And Column Maintenance





*Temperature program // 35 °C, hold for 1.50 min //
30 °C/min to 65 °C, hold 15 min // 20 °C/min to 260 °C for 5 min

Inlet Maintenance Flow Chart



Conclusions

- Start off with the appropriate inlet and correct parameters
- Split is always preferrable/simpler if possible
- Splitless is more challenging
  - Proper injection solvent, solvent effect, retention gap…etc.
- LVI injections of dirty matrix samples will proportionally increase frequency of inlet maintenance
  - Be aware that MMI is more challenging to clean (no gold seal)
- Develop a maintenance schedule that fits your application and sample load (see flow chart previous slide)
- Replace your inlet consumables proactively to avoid column damage
- Don’t worry to much about trimming a full loop or more of column from the inlet side
- Regular “front-end” maintenance is essential
  - Septum, Liner, Gold-seal, Column Trim, Vent trap, Inlet body

When in doubt, please contact us!!

Contact Agilent Chemistries and Supplies Technical Support

1-800-227-9770 option 3, option 3:

Option 1 for GC and GC/MS columns and supplies

Option 2 for LC and LC/MS columns and supplies

Option 3 for sample preparation, filtration, and QuEChERS

Option 4 for spectroscopy supplies

Option 5 for chemical standards

Available in the USA and Canada 8–5, all time zones

gc-column-support@agilent.com

lc-column-support@agilent.com

spp-support@agilent.com

spectro-supplies-support@agilent.com

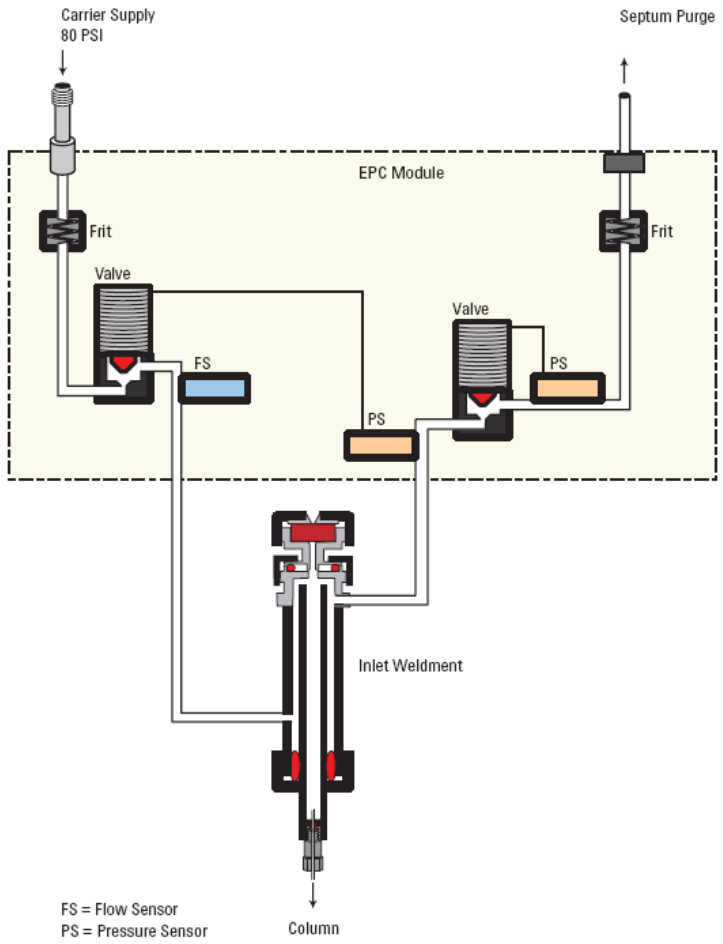
chem-standards-support@agilent.com

Thank you!!

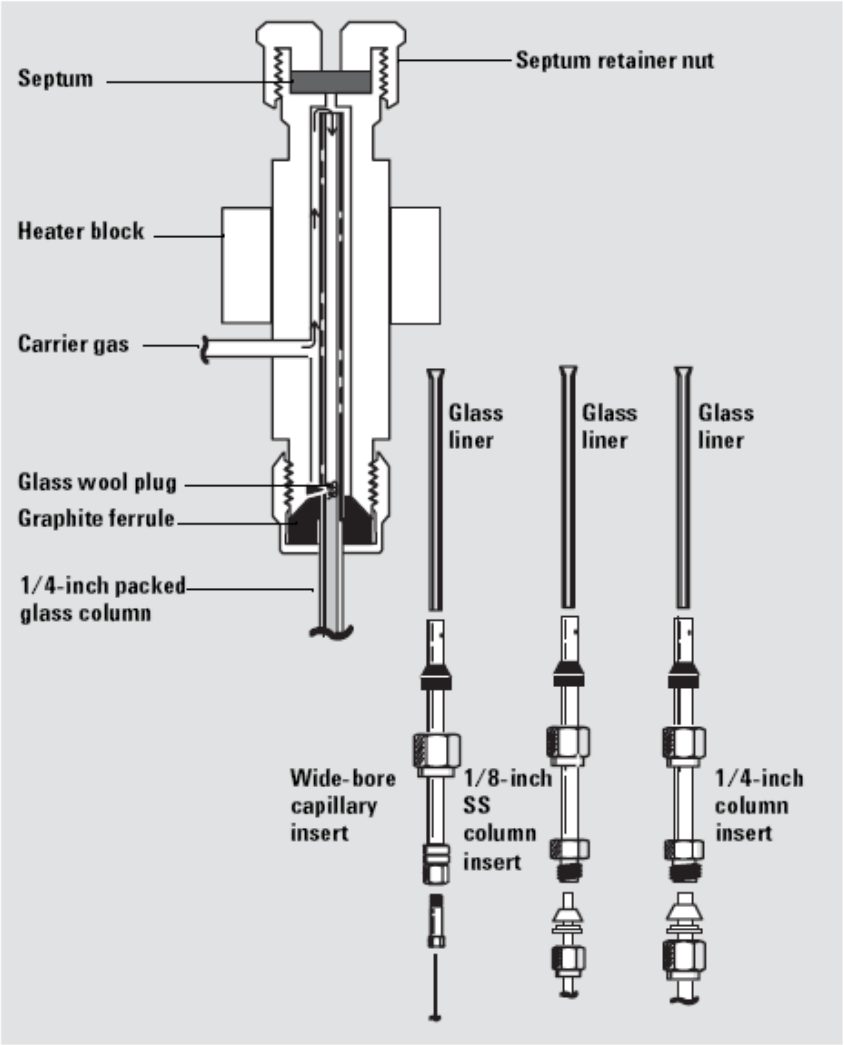
Thank you for your time….

….Questions?

Purged Packed Inlet



Purged Packed



PP Inlet Uses

Packed columns

Can be used with 0.53 mm , or 0.32 mm ID columns when high flows ~10 mL/min are used

When column dimensions are not defined, the inlet functions in a ‘flow’ mode

Packed columns best ran in flow mode, capillary columns preferred to run in pressure mode.

PP Inlet

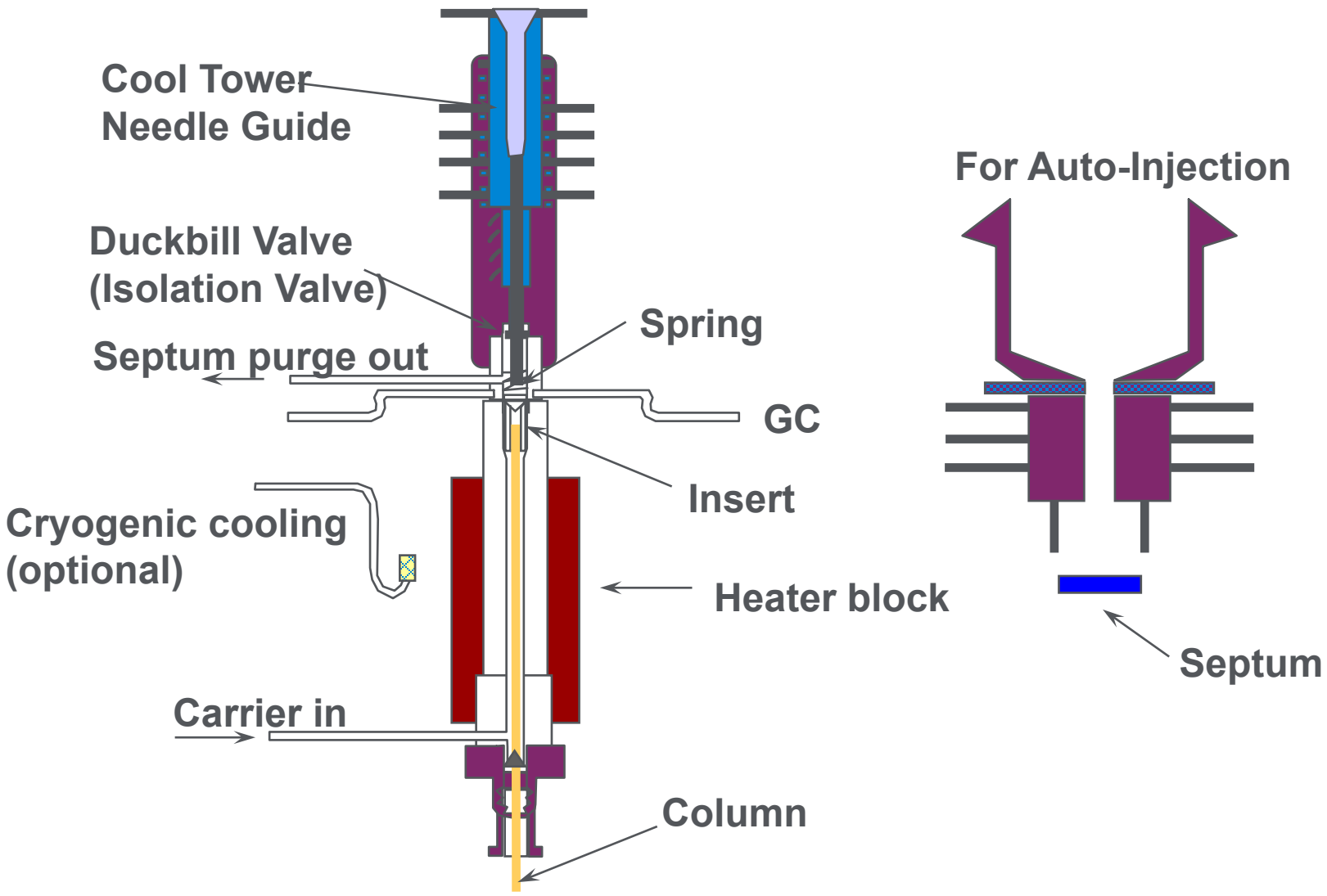
Very small expansion volume

More active than most inlets

- Glass liner helps minimize activity
- Glass packed columns have best reproducibility
- Small surface area of the liner minimizes the amount of active sites

Not Recommended for Capillary Columns smaller than 0.53 mm

COLD ON-COLUMN INJECTION PORT



COC – Mode of Operation

Oven Track Mode

Inlet temperature stays 3°C above the oven temperature

Temperature Programmed Mode

Can program 3 temperature ramps

COC Benefits

Sample Discrimination does not occur

If operated correctly, accurate and precise results are obtained

Can be used to gauge liner activity

Very Gentle sample introduction – limits decomposition of analytes. Good for Labile compounds!

Used for high temperature applications.

- Biodiesel