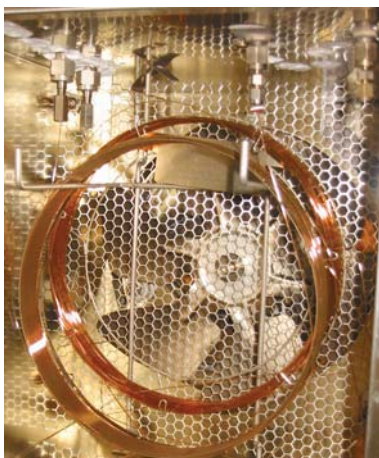


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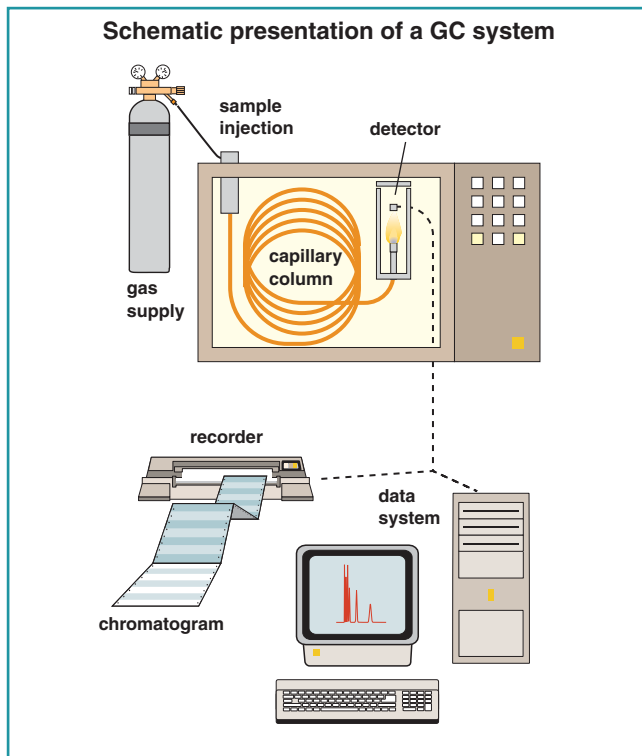
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# Basic principles of GC

## Introduction to GC



In this chapter we want to give a short and general introduction for the beginner in gas chromatography. By no means this is meant as a complete treatise. For further information please refer to the references given below\*.

### The GC system

The chromatographic system is composed of the chromatograph and a recorder for plotting chromatograms or a data station for generation and evaluation of chromatograms. The chromatograph consists of the sample injector, gas supplies, oven with temperature control for the chromatographic column and the detector.

It would take us too far to describe all injection techniques in detail. We just want to mention the different basic possibilities of direct and indirect sample injection. With **direct** injection the sample is introduced into the column without contact with other parts from glass or metal (on column injection). With **indirect** techniques the sample is injected into an evaporator. The vapour then is transferred into the column either completely or partially (split technique). With both techniques the injection can take place at low temperatures, at high temperatures or with temperature programming.

The gas supply unit of a chromatograph has to provide all gases needed for a separation: the carrier gas and e.g. the burner gases for the flame ionisation detector (FID).

The detector indicates a substance by generation of a more or less intense electrical signal (response). Analogue (recorder) or digital (computer) processing of these signals

produces the chromatogram or a numerical report. Some detectors are specific for certain classes of substances or for certain elements (P, N, etc.).

### The separation process

The chromatographic separation is achieved by repeated distribution of each sample component between two phases. One of these phases is stationary. The second, the mobile phase moves along this stationary phase.

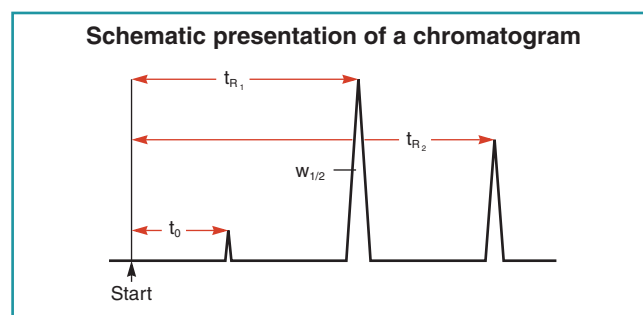
In Gas Chromatography (GC) the mobile phase is always a gas (mostly  $N_2$ ,  $H_2$ , He). The stationary phase in GSC (Gas Solid Chromatography or adsorption chromatography) is a porous polymer solid, while in GLC (Gas Liquid Chromatography or partition chromatography) the stationary phase is a mostly viscous gumlike liquid. Packed columns are completely filled with a packing, liquid stationary phases being coated onto an inert support. Capillary columns do not require a support, because their inner wall is coated with the stationary phase (WCOT = Wall Coated Open Tubular).

Transport of the components is achieved exclusively in the gas phase, separation is accomplished in the stationary phase.

The quality of a separation (resolution) depends on how long the components to be separated stay in the stationary phase and on how often they interact with this phase (selectivity).

The type of interaction between component and phase (selectivity) is determined by the functional groups. The polarity of the phase is a function of stationary phase substituents.

### The chromatogram



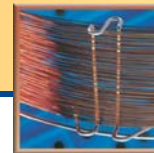
A chromatogram consists of a base line and a number of peaks.

The area of a peak allows quantitative determinations.

Starting point of a chromatogram is the time of injection of a dissolved sample. The time interval between a peak and the point of injection is called retention time  $t_R$ . A component can be identified by its retention time (qualitative determination). The retention time is the sum of the residence time of a solute in the mobile phase ( $t_0$ ) and in the stationary phase ( $t_{R'} = \text{net retention time}$ );

$$t_{R_1} = t_0 + t_{R_1}'$$

$t_0$  is also known as dead time. It is the time required by a component to migrate through the chromatographic system without any interaction with the stationary phase (also called air or gas peak). The net retention time  $t_{R_1}'$  is the difference



## Introduction to GC

between total retention time  $t_{R_i}$  and dead time  $t_0$ . It indicates how long a substance stays in the stationary phase.

$$t_{R_i}' = t_{R_i} - t_0$$

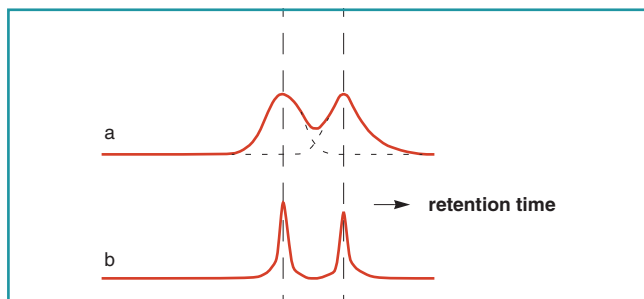
The capacity factor ( $k'$ ) is a measure for the position of a sample peak in the chromatogram. The capacity factor is specific for a given compound and constant under constant conditions.

$$k_i' = \frac{t_{R_i} - t_0}{t_0}$$

The relative retention ( $\alpha$ ), also called separation factor or selectivity coefficient, is defined as

$$\alpha = \frac{k_2'}{k_1'}$$

i.e. it is the ratio of two capacity factors, the reference substance always being in the denominator. The relative retention does not provide any information on the quality of a separation, since for equal values of  $\alpha$  two very broad peaks may overlap, (as shown in trace a), or may be completely resolved (as in trace b), if they are correspondingly narrow.



For this reason the peak width at half height ( $w_{1/2}$ ) is taken into account when considering the resolution  $R$  according to

$$R = \frac{t_{R_2} - t_{R_1}}{(w_{1/2})_2 + (w_{1/2})_1}$$

The resolution  $R$  is a measure for the quality of a separation. The separation number  $SN$  is another value indicating the quality of a separation. It defines how many peaks can be resolved between two members of a homologous series of e.g. n-paraffins.

$$SN = \frac{t_{R_2} - t_{R_1}}{(w_{1/2})_2 + (w_{1/2})_1} - 1$$

If retention times are not too small,  $SN$  can be determined in a temperature programme.

The number of theoretical plates ( $N_{th}$ ) characterises the quality of a column (it should be determined for  $k' > 5$ ):

$$N_{th} = 5.54 \cdot \left( \frac{t_{R_i}}{w_{1/2}} \right)^2$$

The height equivalent to a theoretical plate ( $h$ , HETP) is calculated by dividing the length  $L$  of the column by the number of theoretical plates  $N_{th}$ :

$$h = \text{HETP} = \frac{L}{N_{th}}$$

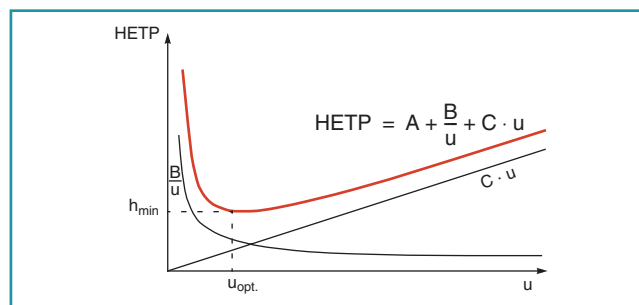
Such a plate is of course a theoretical hypothesis, representing that portion of a column in which the partition equilibrium is established once. The smaller this value the better works the column.

The relation between  $N$ ,  $R$  and  $k'$  is

$$R = \frac{1}{4} \cdot \frac{\alpha - 1}{\alpha} \cdot \frac{k_i'}{k_i' + 1} \cdot \sqrt{N_{th}}$$

From this formula the number of plates  $N_{th}$  required for a given resolution  $R$  can be calculated.

The Van Deemter equation shows how the plate height  $h$  depends on the flow velocity  $u$ :



$A$  = Eddy diffusion;  $A$  is a function of packing uniformity; for WCOT capillary columns  $A$  equals 0 (WCOT = Wall Coated Open Tubular)

$B$  = molecular axial diffusion;  $B$  is a function of the diffusion coefficient of the component in the respective carrier gas

$C$  = resistance to mass transfer

In practice often higher velocities than  $u_{opt}$  are chosen, if separation efficiency is sufficient, since higher carrier velocities mean shorter retention times.

### \* References

D. Rood, "A practical guide to care, maintenance and troubleshooting of capillary gas chromatographic systems", 2nd edition, Hüthig Verlag, Heidelberg, 1995

W. Blum, R. Aichholz "Hochtemperatur-Gas-Chromatographie", Hüthig Verlag, Heidelberg, 1991

G. Schomburg, "Gas Chromatography, A Practical Course", Verlag Chemie, Weinheim, 1990

K. Grob, "Classical Split and Splitless Injection Techniques in Capillary GC", Hüthig Verlag, Heidelberg, 1986

K. Grob, "Making and Manipulation of Capillary Columns for Gas Chromatography", Hüthig Verlag, Heidelberg, 1986

P. Sandra, "Sample Introduction in Capillary Gas Chromatography, Volume 1", Hüthig Verlag, Heidelberg, 1985

E. Leibnitz, H. G. Struppe, "Handbuch der Gas-Chromatographie", Akademische Verlagsgesellschaft Geest u. Portig KG, Leipzig, Germany, 1984

P. Sandra, "Fundamentals: Resolution – Definition and Nomenclature", J. High Res. Chromatogr. **82** (1989) 82 – 86

P. Sandra, "Fundamentals: Resolution – Column Efficiency", J. High Res. Chromatogr. **82** (1989) 273 – 277



# Capillary columns for GC

## Brief selection guide for capillary columns

The large number of stationary phases and the variability of column parameters have caused a considerable diversification of our column programme. MN now offers more than 30 different phases with a total of more than 1300 Cat. Nos. For this reason especially the beginner may have some problems to select the capillary column best suiting his particular separation needs. This is why we will briefly explain the most important criteria for column selection.

A capillary column is characterised by the following parameters:

e.g. Cat. No. 726325.25

30 m x 0.32 mm ID OPTIMA® 5, 1.0 µm film

A

B

C

D

E

A = length

B = inner diameter

C = type of chemical bonding, immobilisation

D = polarity of the stationary phase

E = film thickness

All these parameters have to be optimised for each particular chromatographic task.

### A. Length

The separation efficiency (correctly speaking the number of plates  $n$ ) of a capillary column is directly proportional to the length. However, the same relation is true for the retention time and thus for the total analysis time, making it desirable to use columns as short as possible. For routine separations in general 25 m or shorter will be sufficient with the advantage of short analysis times. For difficult problems such as the separation of complex mixtures with about 50 components or more 60 m columns may be necessary.

Use of longer columns is not recommended. Doubling the column length will only result in a 40% increase in resolution, since the resolution is proportional to the square root of the length. However, the time needed for an isothermal analysis will be doubled.

### B. Inner diameter

The inner diameter also influences the separation efficiency of a capillary column: the lower the inner diameter the higher is the theoretically possible number of plates per meter. This will increase the resolution of the column, which is often required for complex sample mixtures. Due to the low sample capacity one normally has to work with split injection. Increasing the inner diameter while keeping the film thickness constant will increase the capacity. This is especially important for trace analyses and/or for the injection of larger sample volumes. If you halve the diameter of the column while keeping the film thickness constant, the capacity is also reduced by 50%. As a general rule one can say: a column with 0.32 mm ID and a film thickness of 0.25 µm has a maximum capacity of 100 ng/component. Overloading the column results in a loss of resolution.

### a) 0.1 to 0.2 mm inner diameter

OPTIMA® columns with this diameter are especially recommended for GC-MS with the advantage of high resolution and short retention times with low carrier gas flows.

### b) 0.25 mm inner diameter

Columns with this diameter are used for the analysis of complex mixtures. They are recommended as routine columns for high resolution, especially in research applications.

### d) 0.32 mm inner diameter

A column with 0.32 mm ID is **the** column for routine analyses with short retention times, yet increased capacity. With suitable film thickness it is the column of choice for trace analyses and on-column or splitless injection techniques. If you want to use a mass selective detector (MSD), you are often limited to smaller diameters, because many vacuum pumps cannot handle the high flow rates required for columns with larger diameters.

### e) 0.53 mm inner diameter

Compared to packed columns these capillaries show more inert surfaces and higher reproducibility with at least equal separation efficiency. They are not only **the** replacement for packed columns, but **the** capillary for rapid separations with inert surface and highest capacity. The inner diameter 0.53 mm is ideal for use with the thermal conductivity detector.

### C. Immobilisation

**OPTIMA®**: the top quality of fused silica (FS) capillaries from MACHEREY-NAGEL with chemically bonded (immobilised) stationary phases. A special treatment after immobilisation of the phase results in lower column bleeding. An immobilised film of stationary phase tolerates injection of large sample volumes in on-column or splitless sample injection techniques.

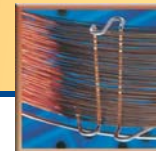
**PERMABOND®**: FS capillary columns, also with immobilised (chemically bonded) stationary phase.

**FS capillary columns** with non-immobilised phases.

### D. Stationary phase

Different substituents in the chemical structures of stationary phases are responsible for the type of interaction (selectivity) between the phase and the solutes to be separated and thus determine the relative retention and the number of theoretical plates required for a given resolution. The stationary phase also limits the temperature range for chromatography. Nonpolar phases separate by volatility only, while polar phases offer additional interactions, which may influence or improve a separation. Selectivity has to be optimised for the critical pair of components or the main component.

You should always select the least polar column which solves your separation problem. About 70% of all separations can be performed on non- to midpolar columns. These columns generally feature high temperature stability. Nonpolar stationary phases (e.g. 100% dimethylpolysiloxane phases) separate components mostly according to the boiling point. Typical analytes are linear hydrocarbons ( $n$ -alkanes).



## Brief selection guide for capillary columns

When increasing the polarity of the phase, e.g. by introduction of phenyl and / or cyanopropyl groups, separation is increasingly influenced by differences in dipole moment and by charge transfer (e.g. for 5 – 50% diphenylpolysiloxane phases). Typical analytes are hydrocarbons, which contain oxygen, sulphur, nitrogen, phosphorus or halogen atoms, unsaturated molecules which can be polarised and aromatics. For components featuring different hydrogen bonding capacities and the ability to form strong hydrogen bonds, polyethylene glycol phases (Carbowax) are the best choice for a separation. Typical analytes are alcohols and carboxylic acids.

### E. Film thickness

Our programme of capillary columns comprises **films from 0.1 to 5.0 µm**. The standard film thickness is 0.25 µm.

If you work with thin films (0.1 – 0.2 µm), in general substances are eluted faster, at lower temperatures and with better resolution than with a thick film (>0.2 µm). For high-boiling compounds, temperature labile or very closely eluting sample substances thin films are very well suited.

Increasing the film thickness will increase the capacity and improve inertness. Thick films are ideal for low-boiling compounds, often eliminating the need for cooling during chromatography, since they increase elution temperatures, i.e. the components are retained more strongly. As a general rule one can say: doubling the film thickness results in an increase in elution temperature of about 15 – 20 °C under isothermal conditions. This is advantageous for aqueous systems as well.

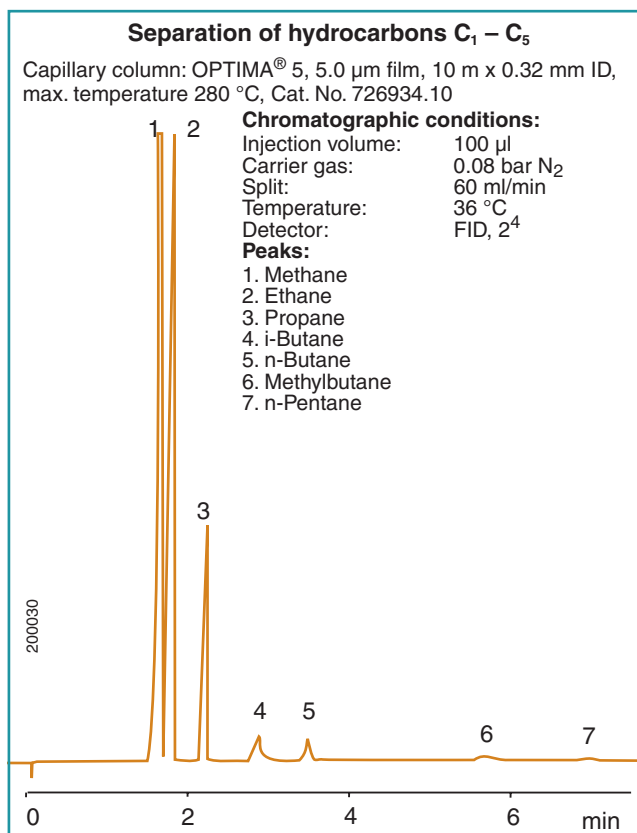
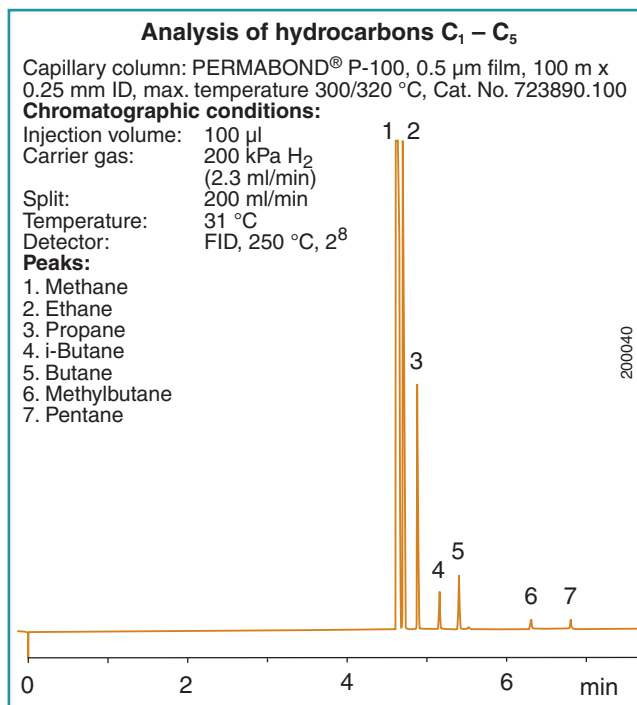
Variation of the film thickness is often better than increasing the column length as is shown in the following chromatograms:

The upper figure shows a separation with the special column PERMABOND® P-100 with 0.5 µm film thickness and 100 m length, while the lower figure shows the chromatogram on a 10 m column with 5 µm film thickness.

The second figure clearly demonstrates the high separation efficiency of a 10 m column with very thick film compared to the 100 m column with thin film.

According to the criteria cited above the following capillaries are suited for the larger part of all applications and can be considered as standard equipment for GC:

1. Cat. No. 726314.25     25 m x 0.32 mm ID  
OPTIMA® 5, 0.25 µm film
2. Cat. No. 726318.25     25 m x 0.32 mm ID  
OPTIMA® 1701, 0.25 µm film
3. Cat. No. 723321.25     25 m x 0.32 mm ID  
OPTIMA® Wax, 0.25 µm film
4. Cat. No. 726440.30     30 m x 0.32 mm ID  
OPTIMA® δ-3, 0.25 µm film  
a suitable substitute for 1. and 2.





# Capillary columns for GC

## OPTIMA® high performance capillary columns

As a result of our efforts in research and development and the continuous improvements in our manufacturing techniques we present OPTIMA® – a series of high performance capillary columns for gas chromatography.

OPTIMA® capillary columns provide

### ● high thermal stability

Improved temperature stability is the reason why OPTIMA® capillary columns can be operated at about 40 °C higher temperatures compared to standard phases. High-boiling solutes (with very low vapour pressures) "normally" have very long retention times and rather broad peak shapes. OPTIMA® columns with their increased operation temperatures elute high-boiling compounds faster and with better peak shapes.

### Maximum operating temperatures for OPTIMA® phases

The first temperature is valid for isothermal operation, the second for short isotherms in a temperature programme. Temperature limits for 0.53 mm ID columns and for columns with film thickness of 3 µm or greater are given with the ordering information on the following pages.

Phase	max. operating temperatures
OPTIMA® 1	340/360 °C
OPTIMA® 5	340/360 °C
OPTIMA® δ-3	340/360 °C
OPTIMA® δ-6	340/360 °C
OPTIMA® 17	320/340 °C
OPTIMA® 1301	300/320 °C
OPTIMA® 1701	300/320 °C
OPTIMA® 624	280/300 °C
OPTIMA® 210	260/280 °C
OPTIMA® 225	260/280 °C
OPTIMA® 240	260/280 °C
OPTIMA® WAX	250/260 °C
OPTIMA® FFAP	250/260 °C

### ● reduced column bleed

Improved manufacturing processes offer capillaries with lower bleed levels, which are especially recommended for GC-MS. Less column bleed yields increased sensitivity and accuracy through a better signal to noise ratio for any kind of detector. Reduced column bleed improves detectability of solutes in qualitative and quantitative GC-MS analyses.

### ● more inert columns due to optimised deactivation

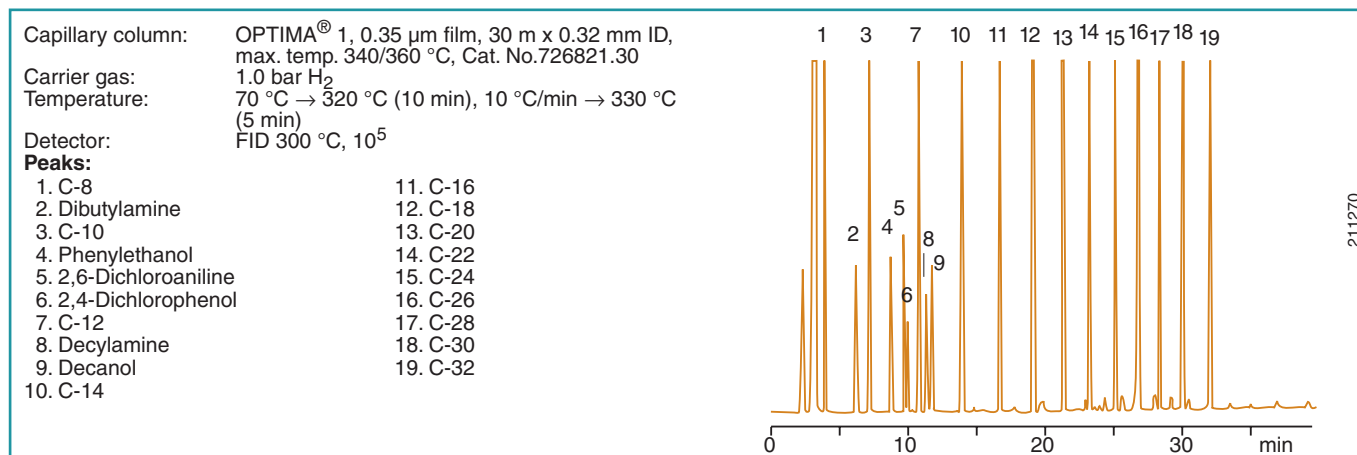
Polar compounds are frequently difficult to analyse, because they often give broad tailing peaks.

Advances in deactivation technology for the OPTIMA® capillaries result in an excellent chromatographic performance yielding improved peak shapes of polar compounds combined with improved efficiency and sensitivity.

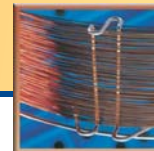
In order to guarantee best industry standard capillaries with highest reproducibility from capillary to capillary OPTIMA® columns have to meet high specifications.

For controlling quality MACHEREY-NAGEL determines the following parameters:

- **efficiency** by measuring the separation number (Trennzahl according to Kaiser) in a temperature programme.
- **polarity** by measuring retention indices
- **bleeding** in a temperature programme with a test mixture including high-boiling hydrocarbons
- **inertness** by measuring the peak height ratio for decylamine/C-12 (for non- to medium polar phases)

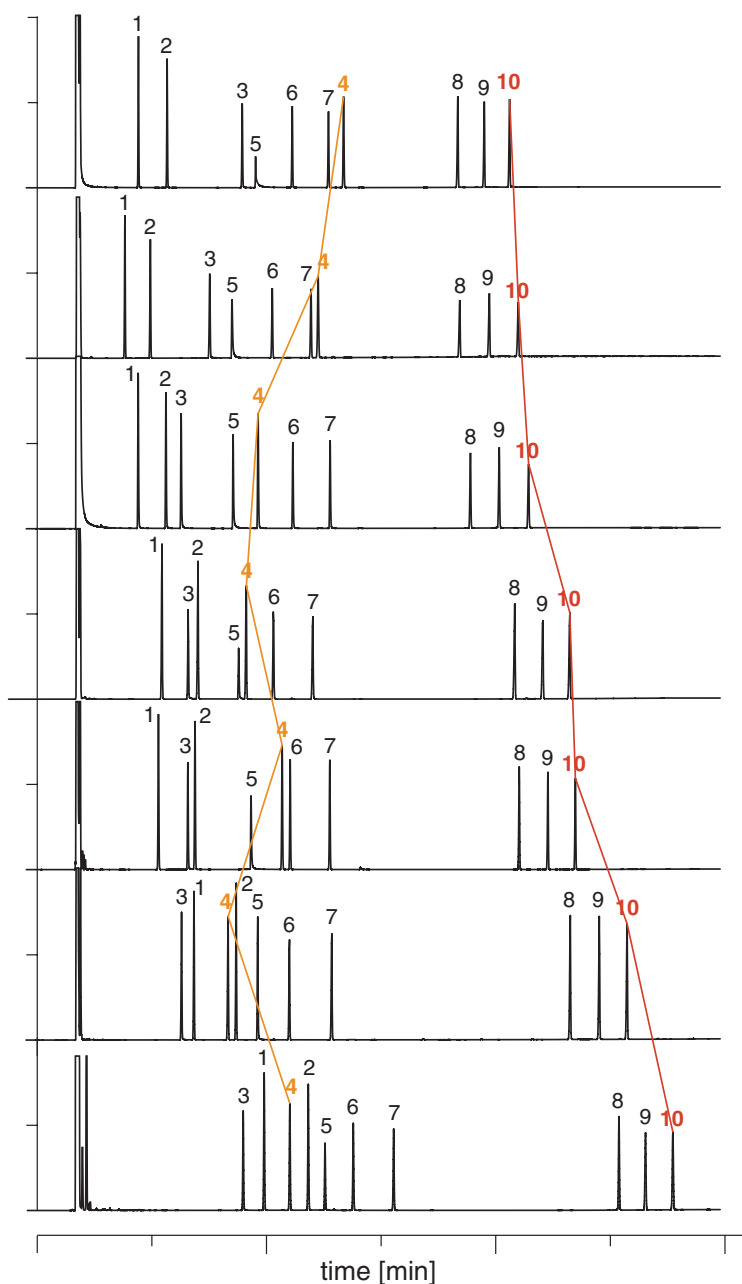


For ordering information of OPTIMA® capillary columns please see pages 324 – 334.



## OPTIMA® high performance capillary columns

### Comparison of separation properties for selected OPTIMA® phases



#### OPTIMA® 240

0.5 µm film  
30 m x 0.32 mm ID  
max. temp. 260/280 °C  
Cat. No. 726096.30

#### OPTIMA® 225

0.5 µm film  
30 m x 0.32 mm ID  
max. temp. 260/280 °C  
Cat. No. 726084.30

#### OPTIMA® 210

0.5 µm film  
30 m x 0.32 mm ID  
max. temp. 260/280 °C  
Cat. No. 726880.30

#### OPTIMA® 1701

0.5 µm film  
30 m x 0.32 mm ID  
max. temp. 320/340 °C  
Cat. No. 726320.30

#### OPTIMA® 17

0.5 µm film  
30 m x 0.32 mm ID  
max. temp. 320/340 °C  
Cat. No. 726744.30

#### OPTIMA® 5

0.5 µm film  
30 m x 0.32 mm ID  
max. temp. 340/360 °C  
Cat. No. 726316.30

#### OPTIMA® 1

0.5 µm film  
30 m x 0.32 mm ID  
max. temp. 340/360 °C  
Cat. No. 726304.30

increasing polarity

#### Chromatographic conditions:

Sample: MN-OPTIMA® test mixture (Cat. No. 722316)  
Injection: 1.0 µl, split 1:50  
Carrier gas: 80 kPa N<sub>2</sub>  
Temperature: 80 °C → T<sub>max</sub> (isothermal), 8 °C/min  
Detector: FID, 260 – 300 °C, 2<sup>6</sup>

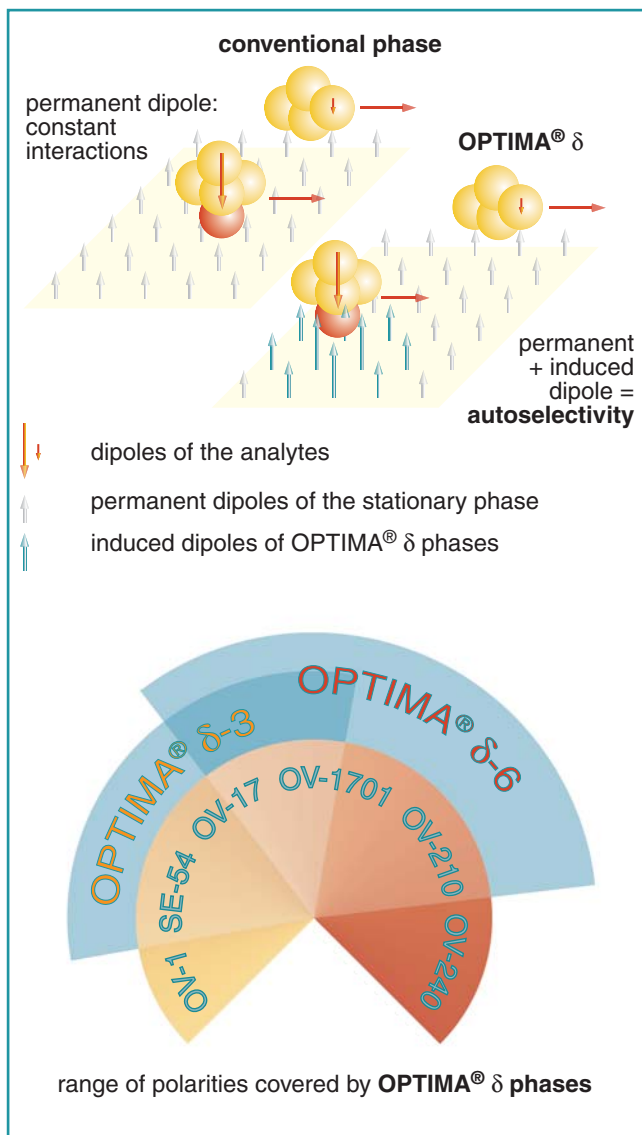
#### Peaks:

- |                           |                       |
|---------------------------|-----------------------|
| 1. Undecane               | 6. Methyl decanoate   |
| 2. Dodecane               | 7. Methyl undecanoate |
| 3. Octanol                | 8. Henicosaane        |
| 4. <b>Dimethylaniline</b> | 9. Docosane           |
| 5. Decylamine             | 10. <b>Tricosane</b>  |



# Capillary columns for GC

## OPTIMA® $\delta$ · the unique family of phases with autoselectivity



All stationary phases in GC offer a selectivity, called polarizability, that is influenced by the sample, but OPTIMA®  $\delta$ -3 and OPTIMA®  $\delta$ -6 offer this valuable feature to a greater extent than any other phase. The polymers consist of cross-linked polysiloxane block polymers with defined composition, and extremely narrow molecular weight distribution, which are exclusively produced for MACHEREY-NAGEL. Especially polar analytes are able to induce a dipole moment in the stationary phase, so that the molecules show stronger interactions with the phase. This enhanced interaction is maintained at higher temperatures, where normally interactions between molecule and phase become reduced due to the Brownian movement. We call this phenomenon "autoselectivity", because the stationary phase adjusts itself to the polarity of the analytes. Thus OPTIMA®  $\delta$  phases cover broad ranges of polarities. Compared with conventional phases, OPTIMA®  $\delta$ -3 polarity ranges from approximately the nonpolar OPTIMA® 5 to the midpolar OPTIMA® 1701, while for OPTIMA®  $\delta$ -6 the polarity covers a range from about the midpolar OPTIMA® 17 to the polar OPTIMA® 210.

Due to this feature, the OPTIMA®  $\delta$  columns show interesting patterns of selectivity. For example, inversions in the sequence of peak elution may occur, which recommends the columns for reference use (e. g. in combination with OPTIMA® 5).

In conventional midpolar phases the polarity is induced by phenyl, but especially by cyano and trifluoromethyl groups. The two latter often cause bleeding, which results in severe problems with some detectors. In contrast, the OPTIMA®  $\delta$  phases show very high temperature limits (340/360 °C), as well as the low bleed levels, which makes them ideal for the use with mass selective (MSD) or phosphorus/nitrogen detectors (PND) in the field of environmental trace analysis.

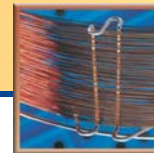
### Key features of the OPTIMA® $\delta$ are:

- Wide range of applications due to autoselectivity
- Outstanding thermal stability similar to non-polar phases
- Very low bleed levels
- Extremely inert
- Medium polar without CN groups

### References

- W. Röder, D. Lennartz, GIT 3/99, p. 226  
R. Looser, K. Ballschmiter, J. Chromatogr. **836** (1999), 271-284  
R. Baycan-Keller, M. Oehme, J. Chromatogr. **837** (1999), 201 – 210





## OPTIMA® $\delta$ · the unique family of GC phases with autoselectivity

### Analysis of isomeric phenols

Isomeric phenols, such as chloro- and nitrophenols, are difficult to analyse with standard GC phases (e.g. OPTIMA® 5 or OPTIMA® 17) because of coelutions. The autoselective OPTIMA®  $\delta$ -3 is able to separate all 22 phenols due to stronger interactions occurring with more polar molecules, because polar analytes induce a dipole moment in the phase of the OPTIMA®  $\delta$ -3.

Capillary column: OPTIMA®  $\delta$ -3, 0.25  $\mu$ m film, 60 m x 0.25 mm ID, max. temperature 340/360 °C, Cat. No. 726420.60

#### Chromatographic conditions:

Injection: 1.0  $\mu$ l, split 1:80

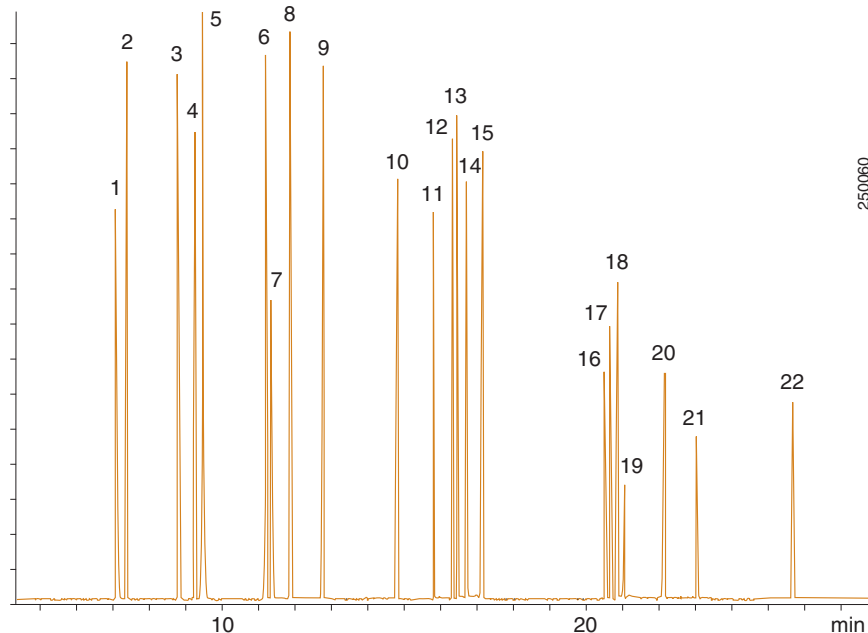
Carrier gas: He, 1.3 bar

Temperature: 60 °C (3 min)  $\rightarrow$  320 °C, 6 °C/min

Detector: MSD HP 5971

#### Peaks:

1. Phenol
2. 2-Chlorophenol
3. 2-Methylphenol
4. 4-Methylphenol
5. 3-Methylphenol
6. 2,4-Dimethylphenol
7. 2-Nitrophenol
8. 2,4-Dichlorophenol
9. 2,6-Dichlorophenol
10. 4-Chloro-3-methylphenol
11. 2,3,5-Trichlorophenol
12. 2,4,6-Trichlorophenol
13. 2,4,5-Trichlorophenol
14. 2,3,4-Trichlorophenol
15. 2,3,6-Trichlorophenol
16. 2,3,5,6-Tetrachlorophenol
17. 2,3,4,5-Tetrachlorophenol
18. 2,3,4,6-Tetrachlorophenol
19. 2,4-Dinitrophenol
20. 3,4,5-Trichlorophenol
21. 2-Methyl-4,6-dinitrophenol
22. 2-Isopropyl-4,6-dinitrophenol



### Separation of organochlorine pesticides (EPA 8081)

Capillary column: OPTIMA®  $\delta$ -6, 0.2  $\mu$ m film, 50 m x 0.2 mm ID, max. temperature 340/360 °C, Cat. No. 726465.50

#### Chromatographic conditions:

Sample: EPA 8081 organochlorine pesticide calibration mix (Restek), 200  $\mu$ g/ml each in toluene : hexane (1 : 1)

Injection volume: 1  $\mu$ l, Split 1:30

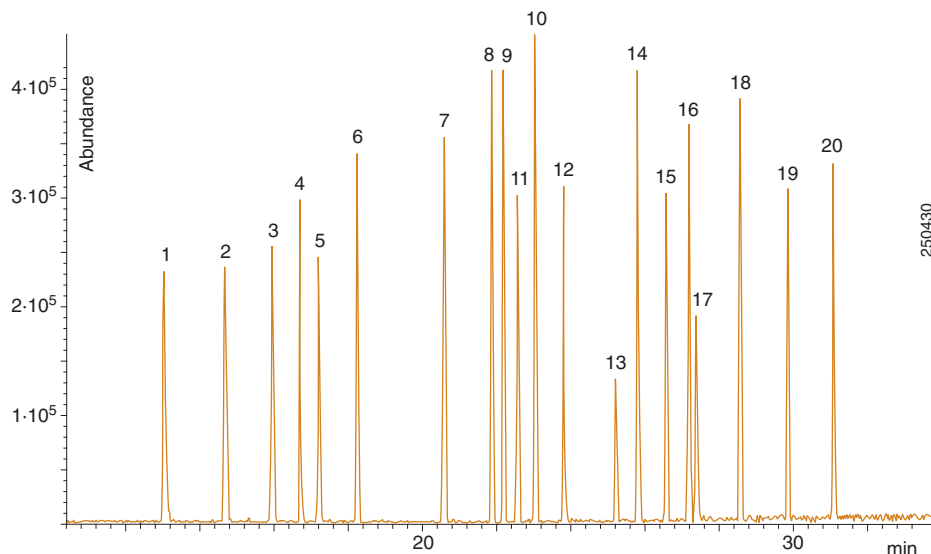
Carrier gas: 2.0 bar He

Temperature: 180 °C  $\rightarrow$  300 °C  
(10 min), 4.0 °C/min

Detector: MSD HP 5971

#### Peaks:

1.  $\alpha$ -BHC
2.  $\gamma$ -BHC (lindane)
3.  $\beta$ -BHC
4. Heptachlor
5.  $\delta$ -BHC
6. Aldrin
7. Heptachlor epoxide
8.  $\gamma$ -Chlordane
9.  $\alpha$ -Chlordane
10. Endosulfan I
11. 4,4'-DDE
12. Dieldrin
13. Endrin
14. 4,4'-DDD
15. Endosulfan II
16. 4,4'-DDT
17. Endrin aldehyde
18. Endosulfan sulphate
19. Methoxychlor
20. Endrin ketone











# Capillary columns for GC

## OPTIMA® high performance capillary columns

# Optima® δ-3

Unique from MN, no similar phases

-  Max. temperature for isothermal operation 340 °C, max. temperature for short isotherms in a temperature programme 360 °C
-  Autoselectivity resulting in a wide range of polarities from approximately the non-polar OPTIMA® 5 to the midpolar OPTIMA® 1701
-  Analytes determine the polarity of the phase
-  Medium polar without CN groups
-  Ideal for MSD and PND detectors
-  USP G49

### Separation of organophosphorus pesticides (EPA 8140/8141) on OPTIMA® δ-3

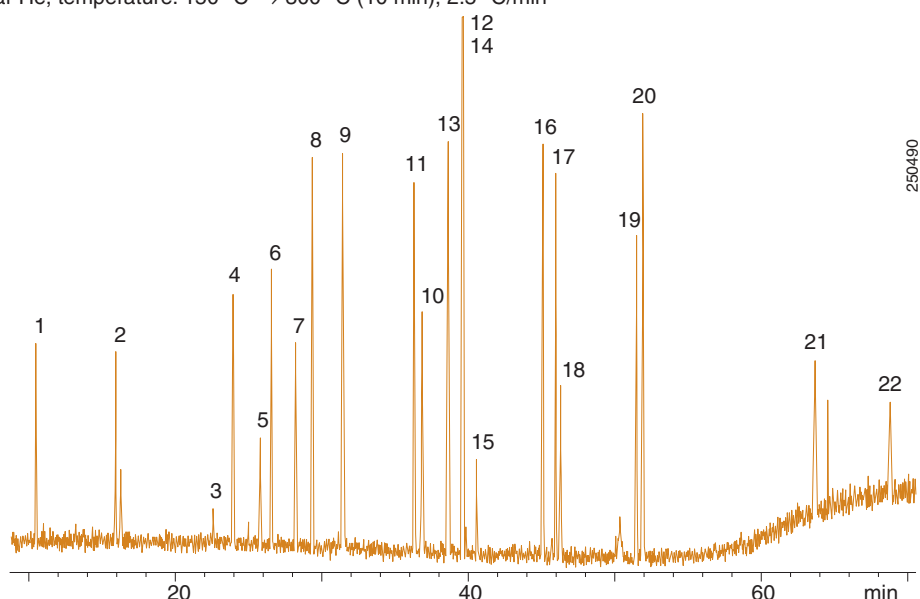
Capillary column: OPTIMA® δ-3, 0.2 µm film, 50 m x 0.2 mm ID, max. temperature 340/360 °C, Cat. No. 726400.50

**Chromatographic conditions:** sample EPA 8140 OP pesticide calibration mix (Restek), 200 µg/ml each in hexane : acetone = 95 : 5  
Injection: 1 µl, split 1 : 30, carrier gas: 2.0 bar He, temperature: 150 °C → 300 °C (10 min), 2.5 °C/min

Detector: MSD HP 5971

**Peaks:**

1. Dichlorvos
2. Mevinphos
3. Demeton-s
4. Ethoprop
5. Naled
6. Phorate
7. Demeton-o
8. Diazinon
9. Disulfoton
10. Parathion-methyl
11. Ronnel
12. Fenthion
13. Chlorpyrifos
14. Trichloronate
15. Merphos
16. Stirofos
17. Tokuthion
18. Merphos oxidation product
19. Fensulfothion
20. Bolstar
21. Azinphos-methyl
22. Coumaphos

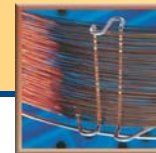


Ordering information	Cat. No. for column length of					
	10 m	20 m	25 m	30 m	50 m	60 m
<b>0.1 mm ID (0.4 mm OD)</b>						
0.10 µm film	<b>726410.10</b>	<b>726410.20</b>	–	–	–	–
<b>0.2 mm ID (0.4 mm OD)</b>						
0.20 µm film	–	–	<b>726400.25</b>	–	<b>726400.50</b>	–
<b>0.25 mm ID (0.4 mm OD)</b>						
0.25 µm film	–	–	–	<b>726420.30</b>	–	<b>726420.60</b>
0.50 µm film	–	–	–	<b>726421.30</b>	–	–
<b>0.32 mm ID (0.5 mm OD)</b>						
0.25 µm film	–	–	–	<b>726440.30</b>	–	<b>726440.60</b>
0.35 µm film	–	–	–	<b>726441.30</b>	–	<b>726441.60</b>
1.00 µm film	–	–	–	<b>726442.30</b>	–	<b>726442.60</b>
<b>0.53 mm ID (0.8 mm OD)</b>						
1.00 µm film	–	–	–	<b>726443.30</b>	–	–

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.






# Capillary columns for GC



## OPTIMA® high performance capillary columns

**Optima® δ-6**

Unique from MN, no similar phases

-  Max. temperature for isothermal operation 340 °C, max. temperature for short isotherms in a temperature programme 360 °C
-  Autoselectivity resulting in a wide range of polarities from approximately the non-polar OPTIMA® 17 to the midpolar OPTIMA® 210
-  Analytes determine the polarity of the phase
-  Medium polar without CN groups
-  Ideal for MSD and PND detectors

### Separation of organophosphorus pesticides (EPA 8140/8141) on OPTIMA® δ-6

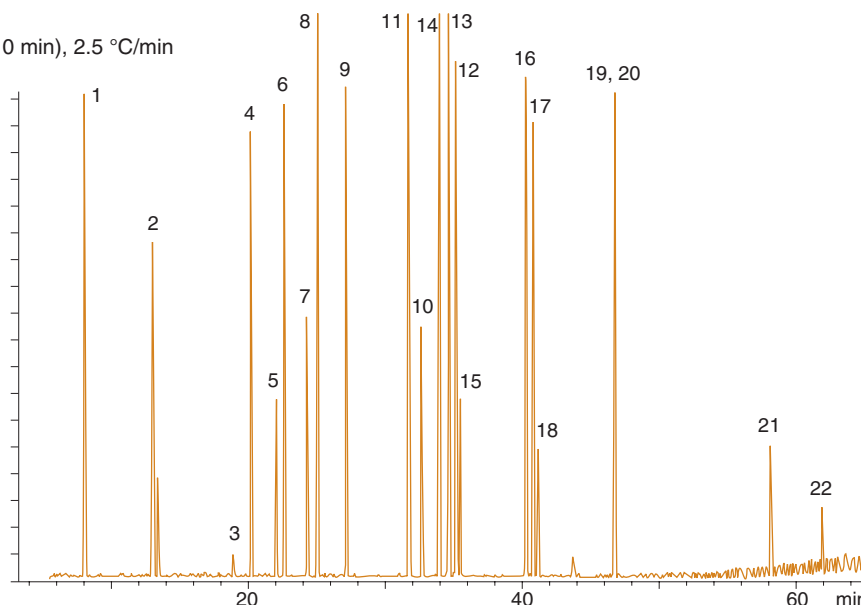
Capillary column: OPTIMA® δ-6, 0.2 µm film, 50 m x 0.2 mm ID, max. temperature 340/360 °C, Cat. No. 726465.50

#### Chromatographic conditions:

Sample: EPA 8140 OP pesticide calibration mix (Restek), 200 µg/ml each in hexane : acetone = 95 : 5  
 Injection volume: 1 µl, split 1:30  
 Carrier gas: 2.0 bar He  
 Temperature: 150 °C → 300 °C (10 min), 2.5 °C/min  
 Detector: MSD HP 5971

#### Peaks:

1. Dichlorvos
2. Mevinphos
3. Demeton-s
4. Ethoprop
5. Naled
6. Phorate
7. Demeton-o
8. Diazinon
9. Disulfoton
10. Parathion-methyl
11. Ronnel
12. Fenthion
13. Chlorpyrifos
14. Trichloronate
15. Merphos
16. Stirofos
17. Tokuthion
18. Merphos oxidation product
19. Fensulfthion
20. Bolstar
21. Azinphos-methyl
22. Coumaphos



250420

Ordering information	Cat. No. for column length of				
	10 m	25 m	30 m	50 m	60 m
<b>0.1 mm ID (0.4 mm OD)</b>					
0.10 µm film	<b>726490.10</b>	-	-	-	-
<b>0.2 mm ID (0.4 mm OD)</b>					
0.20 µm film	-	<b>726465.25</b>	-	<b>726465.50</b>	-
<b>0.25 mm ID (0.4 mm OD)</b>					
0.25 µm film	-	-	<b>726470.30</b>	-	<b>726470.60</b>
<b>0.32 mm ID (0.5 mm OD)</b>					
0.25 µm film	-	-	<b>726480.30</b>	-	<b>726480.60</b>
0.35 µm film	-	-	<b>726481.30</b>	-	<b>726481.60</b>
1.00 µm film	-	-	<b>726482.30</b>	-	<b>726482.60</b>
<b>0.53 mm ID (0.8 mm OD)</b>					
1.00 µm film	-	-	<b>726483.30</b>	-	-

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

On request, all columns can be supplied on a 5 inch (13 cm) cage for the Agilent GC 6850. For ordering, please add an E at the end of the catalogue number (e.g. 726470.30E)

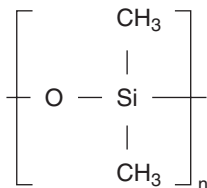


# Capillary columns for GC

## OPTIMA® high performance capillary columns

Optima® 1

100% dimethylpolysiloxane



For columns with 0.1 – 0.32 mm ID and films < 3 µm the max. temperature for isothermal operation is 340 °C, the max. temperature for short isotherms in a temperature programme is 360 °C  
for 0.53 mm ID columns with films < 3 µm the max. temperatures are 320 and 340 °C, resp.  
for thick film columns with films ≥ 3 µm the max. temperatures are 300 and 320 °C, resp.

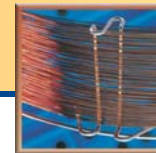
- Nonpolar
- Separation of components according to boiling points
- Thick film columns ≥ 3 µm film are especially recommended for solvent analysis
- Similar phases: OV-1, DB-1, SE-30, HP-1, Ultra-1, SPB-1, CP-SIL 5 CB, Rtx-1, 007-1, BP1, MDN-1, AT-1, ZB 1, OV 101
- USP G2

Ordering information	Cat. No. for column length of							
	10 m	12 m	15 m	20 m	25 m	30 m	50 m	60 m
<b>0.1 mm ID (0.4 mm OD)</b>								
0.10 µm film	<b>726024.10</b>	–	–	<b>726024.20</b>	–	–	–	–
0.40 µm film	–	–	–	<b>726025.20</b>	–	–	–	–
<b>0.2 mm ID (0.4 mm OD)</b>								
0.10 µm film	–	–	–	–	<b>726832.25</b>	–	–	–
0.20 µm film	–	<b>726834.12</b>	–	–	<b>726834.25</b>	–	<b>726834.50</b>	–
0.35 µm film	–	<b>726837.12</b>	–	–	<b>726837.25</b>	–	<b>726837.50</b>	–
0.50 µm film	–	–	–	–	–	–	<b>726839.50</b>	–
<b>0.25 mm ID (0.4 mm OD)</b>								
0.10 µm film	<b>726038.10</b>	–	<b>726038.15</b>	–	<b>726038.25</b>	<b>726038.30</b>	–	<b>726038.60</b>
0.25 µm film	<b>726050.10</b>	–	<b>726050.15</b>	–	<b>726050.25</b>	<b>726050.30</b>	<b>726050.50</b>	<b>726050.60</b>
0.50 µm film	<b>726081.10</b>	–	–	–	<b>726081.25</b>	<b>726081.30</b>	<b>726081.50</b>	<b>726081.60</b>
1.00 µm film	–	–	–	–	<b>726802.25</b>	<b>726802.30</b>	<b>726802.50</b>	<b>726802.60</b>
<b>0.32 mm ID (0.5 mm OD)</b>								
0.10 µm film	<b>726301.10</b>	–	–	–	<b>726301.25</b>	<b>726301.30</b>	<b>726301.50</b>	<b>726301.60</b>
0.25 µm film	<b>726302.10</b>	–	<b>726302.15</b>	–	<b>726302.25</b>	<b>726302.30</b>	<b>726302.50</b>	<b>726302.60</b>
0.35 µm film	–	–	–	–	<b>726821.25</b>	<b>726821.30</b>	<b>726821.50</b>	<b>726821.60</b>
0.50 µm film	<b>726304.10</b>	–	–	–	<b>726304.25</b>	<b>726304.30</b>	<b>726304.50</b>	<b>726304.60</b>
1.00 µm film	<b>726323.10</b>	–	<b>726323.15</b>	–	<b>726323.25</b>	<b>726323.30</b>	<b>726323.50</b>	<b>726323.60</b>
3.00 µm film	–	–	–	–	<b>726805.25</b>	<b>726805.30</b>	<b>726805.50</b>	<b>726805.60</b>
5.00 µm film	<b>726931.10</b>	–	–	–	<b>726931.25</b>	<b>726931.30</b>	<b>726931.50</b>	–
<b>0.53 mm ID (0.8 mm OD)</b>								
0.50 µm film	–	–	–	–	<b>726519.25</b>	<b>726519.30</b>	–	–
1.00 µm film	<b>726529.10</b>	–	<b>726529.15</b>	–	<b>726529.25</b>	<b>726529.30</b>	–	–
2.00 µm film	<b>726521.10</b>	–	–	–	<b>726521.25</b>	<b>726521.30</b>	–	–
5.00 µm film	<b>726926.10</b>	–	–	–	<b>726926.25</b>	<b>726926.30</b>	<b>726926.50</b>	–

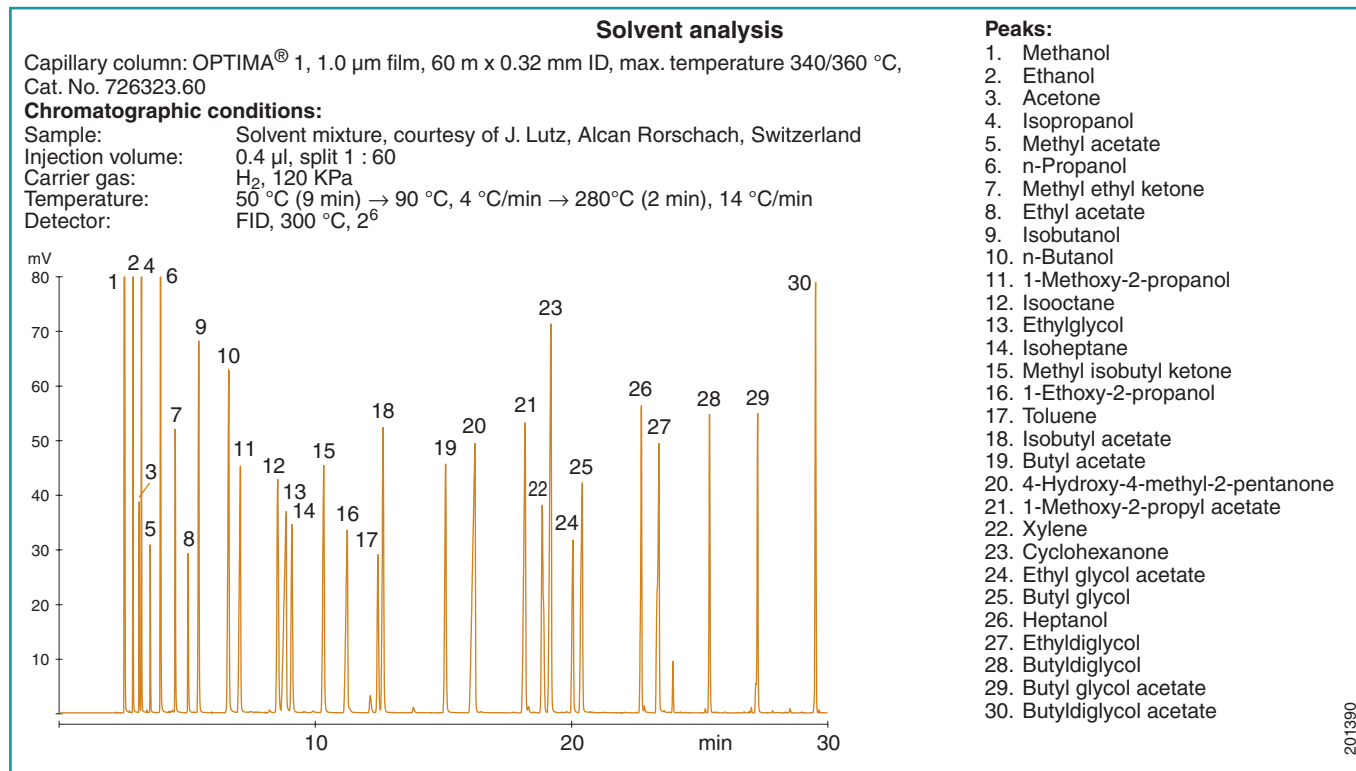
In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.

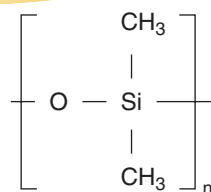
# Capillary columns for GC



## OPTIMA® high performance capillary columns



100% dimethylpolysiloxane



- Max. temperature for isothermal operation 340 °C, max. temperature for short isotherms in a temperature programme 360 °C
- Selectivity identical to OPTIMA® 1
- Phase with lowest bleeding
- Ideal for GC/MS and ECD applications and general analyses at trace level

Ordering information	Cat. No. for column length of					
	12 m	15 m	25 m	30 m	50 m	60 m
<b>0.2 mm ID (0.4 mm OD)</b>						
0.20 µm film	–	–	<b>726201.25</b>	–	<b>726201.50</b>	–
0.35 µm film	<b>726203.12</b>	–	–	–	–	–
<b>0.25 mm ID (0.4 mm OD)</b>						
0.25 µm film	–	<b>726205.15</b>	–	<b>726205.30</b>	–	<b>726205.60</b>
<b>0.32 mm ID (0.5 mm OD)</b>						
0.25 µm film	–	–	–	<b>726202.30</b>	–	<b>726202.60</b>

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

On request, all columns can be supplied on a 5 inch (13 cm) cage for the Agilent GC 6850. For ordering, please add an E at the end of the catalogue number (e.g. 726470.30E)

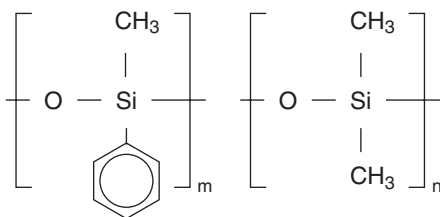


# Capillary columns for GC

## OPTIMA® high performance capillary columns

# Optima® 5

5% phenyl – 95% dimethylpolysiloxane



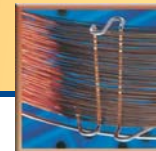
For columns with 0.1 – 0.32 mm ID and films < 3 µm the max. temperature for isothermal operation is 340 °C, the max. temperature for short isotherms in a temperature programme is 360 °C  
for 0.53 mm ID columns with films < 3 µm the max. temperatures are 320 and 340 °C, resp.  
for thick film columns with films ≥ 3 µm the max. temperatures are 300 and 320 °C, resp.

- Nonpolar
- Standard phase with large range of application
- Suitable for GC/MS (columns with small films)
- Similar phases: SE-54, SE-52, DB-5, HP-5, Ultra-2, SPB-5, CP-SIL 8, Rtx-5, 007-5, BP5, MDN-5, AT-5, ZB-5
- USP G27, G36

Ordering information	Cat. No. for column length of					
	10 m	15 m	25 m	30 m	50 m	60 m
<b>0.1 mm ID (0.4 mm OD)</b>						
0.10 µm film	726846.10	–	–	–	–	–
<b>0.20 mm ID (0.4 mm OD)</b>						
0.10 µm film	–	–	726854.25	–	–	–
0.20 µm film	–	–	726857.25	–	726857.50	–
0.35 µm film	–	–	726860.25	–	726860.50	–
0.50 µm film	–	–	726863.25	–	726863.50	–
<b>0.25 mm ID (0.4 mm OD)</b>						
0.10 µm film	–	–	726911.25	726911.30	726911.50	726911.60
0.25 µm film	726056.10	726056.15	726056.25	726056.30	726056.50	726056.60
0.35 µm film	–	–	726623.25	726623.30	726623.50	726623.60
0.50 µm film	–	–	726099.25	726099.30	726099.50	726099.60
1.00 µm film	–	–	726807.25	726807.30	726807.50	726807.60
<b>0.32 mm ID (0.5 mm OD)</b>						
0.10 µm film	726313.10	726313.15	726313.25	726313.30	726313.50	726313.60
0.25 µm film	–	726314.15	726314.25	726314.30	726314.50	726314.60
0.35 µm film	–	–	726628.25	726628.30	726628.50	726628.60
0.50 µm film	–	–	726316.25	726316.30	726316.50	726316.60
1.00 µm film	–	726325.15	726325.25	726325.30	726325.50	726325.60
3.00 µm film	–	–	726809.25	726809.30	726809.50	726809.60
5.00 µm film	–	726934.15	726934.25	726934.30	–	–
<b>0.53 mm ID (0.8 mm OD)</b>						
0.50 µm film	726523.10	–	726523.25	726523.30	–	–
1.00 µm film	726541.10	726541.15	726541.25	726541.30	–	–
2.00 µm film	726525.10	–	726525.25	726525.30	726525.50	726525.60
5.00 µm film	726916.10	–	726916.25	726916.30	726916.50	–

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

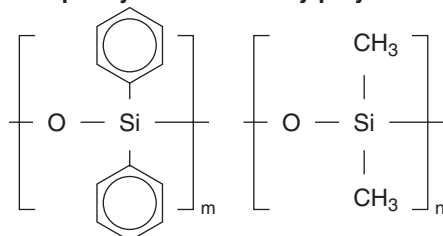
Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.



## OPTIMA® high performance capillary columns

# Optima® 5 MS

5% diphenyl – 95% dimethylpolysiloxane



### Pyrolysis GC of chloroprene rubber

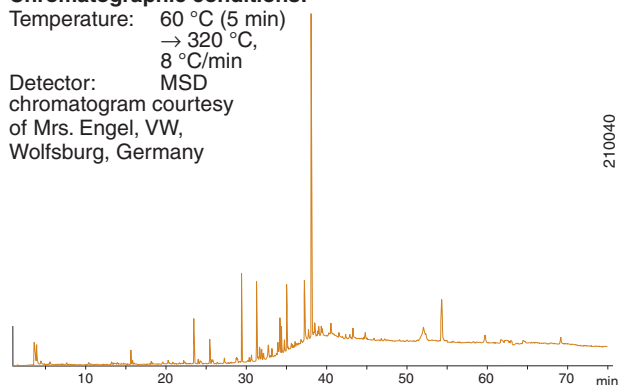
Capillary column: OPTIMA® 5 MS, 1 µm film, 60 m x 0.32 mm ID, max. temperature: 340/360 °C, Cat. No. 726212.60

Method: 1 g solid are dissolved in 10 ml of hexane or methanol, 100 µl of this solution are pyrolysed in a crucible, headspace

#### Chromatographic conditions:

Temperature: 60 °C (5 min)  
→ 320 °C,  
8 °C/min

Detector: MSD  
chromatogram courtesy  
of Mrs. Engel, VW,  
Wolfsburg, Germany



Max. temperature for isothermal operation 340 °C, max. temperature for short isotherms in a temperature programme 360 °C

- Selectivity identical to OPTIMA® 5
- **Improved quality – very low bleeding**
- Ideal for GC/MS and ECD applications and general analyses at trace level
- USP G36

### Analysis of PCB (W22 congener mix)

Capillary column: OPTIMA® 5 MS, 0.2 µm film, 50 m x 0.20 mm ID, max. temperature: 340/360 °C, Cat. No. 726210.50

#### Chromatographic conditions:

Sample: PCB-W22 congener mix, 10 µl/ml

Injection: 1 µl

Split: 80 ml/min

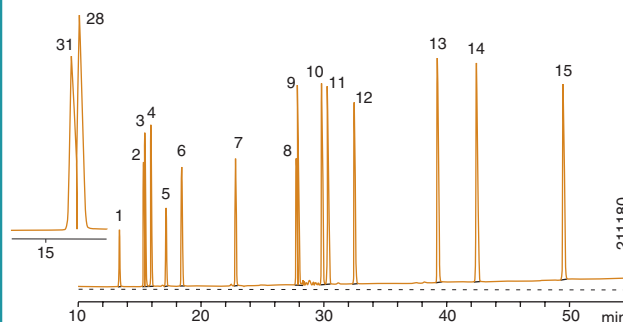
Carrier gas: 0.5 bar He

Temperature: 220 °C → 300 °C (15 min), 1.5 °C/min

Detector: ECD, 300 °C

#### Peaks:

- |           |             |             |
|-----------|-------------|-------------|
| 1. PCB 18 | 6. PCB 44   | 11. PCB 105 |
| 2. PCB 31 | 7. PCB 101  | 12. PCB 138 |
| 3. PCB 28 | 8. PCB 149  | 13. PCB 180 |
| 4. PCB 20 | 9. PCB 118  | 14. PCB 170 |
| 5. PCB 52 | 10. PCB 153 | 15. PCB 194 |



### Ordering information

### Cat. No. for column length of

	12 m	15 m	25 m	30 m	50 m	60 m
<b>0.2 mm ID (0.4 mm OD)</b>						
0.20 µm film	726210.12	–	726210.25	–	726210.50	–
0.35 µm film	726215.12	–	726215.25	–	726215.50	–
<b>0.25 mm ID (0.4 mm OD)</b>						
0.25 µm film	–	726220.15	–	726220.30	–	726220.60
0.50 µm film	–	–	–	726225.30	–	726225.60
1.00 µm film	–	–	–	726226.30	–	–
<b>0.32 mm ID (0.5 mm OD)</b>						
0.25 µm film	–	–	–	726211.30	–	–
0.50 µm film	–	–	–	726213.30	–	–
1.00 µm film	–	–	726212.25	–	726212.50	726212.60

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

On request, all columns can be supplied on a 5 inch (13 cm) cage for the Agilent GC 6850. For ordering, please add an E at the end of the catalogue number (e.g. 726470.30E)

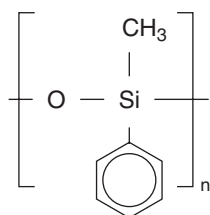


# Capillary columns for GC

## OPTIMA® high performance capillary columns

# Optima® 17

phenylmethylpolysiloxane (50% phenyl)



Max. temperature for isothermal operation 320 °C, max. temperature for short isotherms in a temperature programme 340 °C  
for 0.53 mm ID columns the max. temperatures are 280 and 300 °C, resp.

- Medium polar
- Suitable for higher temperatures
- Preferred applications: steroids, pesticides, drug analyses
- Similar phases: OV-17, DB-17, HP-50+, HP-17, SPB-50, SP-2250, Rtx-50, CP-SIL 24 CB, 007-17, ZB-50
- USP G3

### Analysis of pesticides

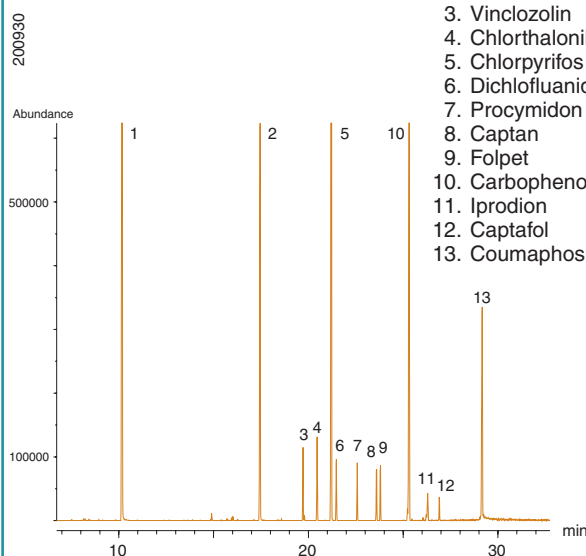
Capillary column: OPTIMA® 17, 0.20 µm film, 25 m x 0.20 mm ID, max. temperature 320/340 °C, Cat. No. 726065.25

#### Chromatographic conditions:

Samples: pesticides, standard of the cantonal laboratory Schaffhausen (Switzerland), 0.1 mg/ml or 0.01 mg/ml each; injection volume 1.0 µl; carrier gas: He, 25 cm/s, 3 sec without split  
Temperature: 100 °C (3 min iso), 8 °C/min → 250 °C, 10 °C/min → 320 °C; detector: MSD HP 5971

#### Peaks:

1. Dichlorphos
2. Naled
3. Vinclozolin
4. Chlorthalonil
5. Chlorpyrifos
6. Dichlofluanid
7. Procymidon
8. Captan
9. Folpet
10. Carbophenothion
11. Iprodion
12. Captafol
13. Coumaphos

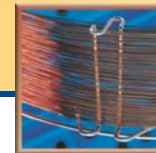


Ordering information	Cat. No. for column length of						
	10 m	12 m	15 m	25 m	30 m	50 m	60 m
<b>0.1 mm ID (0.4 mm OD)</b>							
0.10 µm film	<b>726848.10</b>	–	–	–	–	–	–
<b>0.2 mm ID (0.4 mm OD)</b>							
0.20 µm film	–	<b>726065.12</b>	–	<b>726065.25</b>	–	<b>726065.50</b>	–
0.50 µm film	–	–	–	<b>726066.25</b>	–	<b>726066.50</b>	–
<b>0.25 mm ID (0.4 mm OD)</b>							
0.15 µm film	–	–	–	<b>726742.25</b>	<b>726742.30</b>	<b>726742.50</b>	<b>726742.60</b>
0.25 µm film	–	–	<b>726022.15</b>	<b>726022.25</b>	<b>726022.30</b>	<b>726022.50</b>	<b>726022.60</b>
0.50 µm film	–	–	–	<b>726067.25</b>	<b>726067.30</b>	<b>726067.50</b>	<b>726067.60</b>
<b>0.32 mm ID (0.5 mm OD)</b>							
0.15 µm film	–	–	–	–	<b>726755.30</b>	–	–
0.25 µm film	–	–	–	<b>726351.25</b>	<b>726351.30</b>	<b>726351.50</b>	<b>726351.60</b>
0.35 µm film	–	–	–	<b>726757.25</b>	<b>726757.30</b>	<b>726757.50</b>	<b>726757.60</b>
0.50 µm film	–	–	–	<b>726744.25</b>	<b>726744.30</b>	<b>726744.50</b>	<b>726744.60</b>
<b>0.53 mm ID (0.8 mm OD)</b>							
1.00 µm film	<b>726747.10</b>	–	<b>726747.15</b>	<b>726747.25</b>	<b>726747.30</b>	–	–

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.

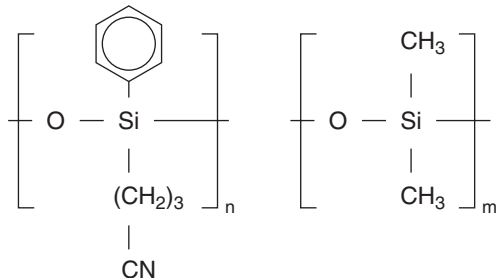




## OPTIMA® high performance capillary columns

# Optima® 1701

14% cyanopropyl-phenyl – 86% dimethylpolysiloxane



Max. temperature for isothermal operation 300 °C, max. temperature for short isotherms in a temperature programme 320 °C  
for 0.53 mm ID columns the max. temperatures are 280 and 300 °C, resp.

- Medium polar
- Special selectivity due to high cyanopropyl content
- Reference column for structure identification, e.g. in combination with OPTIMA® 5
- Film thickness  $\geq 1 \mu\text{m}$  for solvent analyses
- Similar phases: OV-1701, DB-1701, CP-SIL 19 CB, HP-1701, Rtx-1701, SPB-1701, 007-1701, BP10, ZB-1701
- USP G46

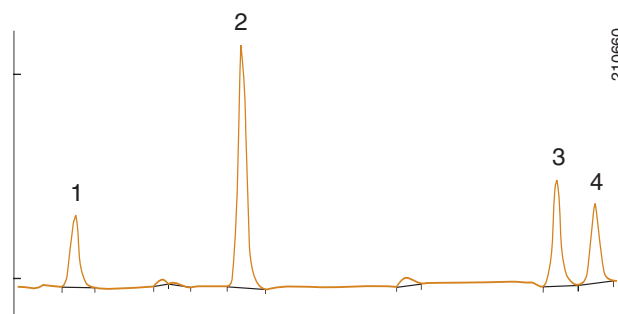
### Analysis of *Fusarium* mycotoxins

F. Walker, B. Meier, Journal of AOAC Int. **81** (1998) 741 – 748  
Capillary column: OPTIMA® 1701, 0.35  $\mu\text{m}$  film, 25 m x 0.32 mm ID, max. temperature 300/320 °C, Cat. No. 726824.25

Injection: 1  $\mu\text{l}$ , 250 °C, splitless  
Carrier gas: N<sub>2</sub>, 30 cm/s linear velocity at 160 °C  
Temperature: 160 °C (3 min) → 240 °C, 6 °C/min → 270 °C, 30 °C/min (3 min)

Detector: <sup>63</sup>Ni-ECD, 320 °C

**Peaks:**  
1. 13.9 min Nivalenol (0.007 ppm)  
2. 15.1 min Deoxynivalenol (0.006 ppm)  
3. 17.3 min 15-*O*-Acetyl-4-deoxynivalenol (0.006 ppm)  
4. 17.6 min 3-Acetyldeoxynivalenol (0.005 ppm)



Ordering information	Cat. No. for column length of					
	10 m	15 m	25 m	30 m	50 m	60 m
<b>0.2 mm ID (0.4 mm OD)</b>						
0.20 $\mu\text{m}$ film	–	–	726841.25	–	726841.50	–
<b>0.25 mm ID (0.4 mm OD)</b>						
0.25 $\mu\text{m}$ film	726058.10	726058.15	726058.25	726058.30	726058.50	726058.60
0.50 $\mu\text{m}$ film	–	–	–	726064.30	–	726064.60
1.00 $\mu\text{m}$ film	–	–	–	726965.30	–	–
<b>0.32 mm ID (0.5 mm OD)</b>						
0.25 $\mu\text{m}$ film	726318.10	726318.15	726318.25	726318.30	726318.50	726318.60
0.35 $\mu\text{m}$ film	–	–	726824.25	726824.30	726824.50	726824.60
0.50 $\mu\text{m}$ film	–	–	726320.25	726320.30	726320.50	726320.60
1.00 $\mu\text{m}$ film	–	–	726929.25	726929.30	726929.50	726929.60
<b>0.53 mm ID (0.8 mm OD)</b>						
1.00 $\mu\text{m}$ film	726545.10	726545.15	726545.25	726545.30	–	–
2.00 $\mu\text{m}$ film	–	726735.15	726735.25	726735.30	726735.50	–

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

On request, all columns can be supplied on a 5 inch (13 cm) cage for the Agilent GC 6850. For ordering, please add an E at the end of the catalogue number (e.g. 726470.30E)

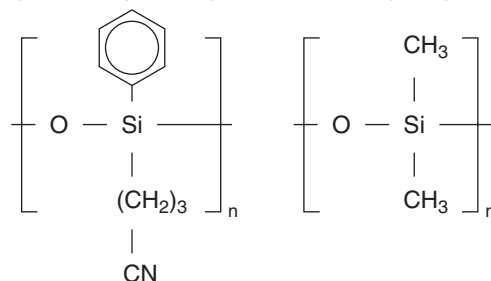


# Capillary columns for GC

## OPTIMA® high performance capillary columns

# Optima® 1301

6% cyanopropyl-phenyl – 94% dimethylpolysiloxane



Max. temperature for isothermal operation 300 °C, max. temperature for short isotherms in a temperature programme 320 °C

- Medium polar
- Ideal for pesticide analyses
- Similar phases: HP-1301, DB-1301, SPB-1301, Rtx-1301, CP-1301, 007-1301
- USP G43

Ordering information	Cat. No. for column length of			
	25 m	30 m	50 m	60 m
<b>0.25 mm ID</b> (0.4 mm OD)				
0.25 µm film	726771.25	726771.30	726771.50	726771.60
<b>0.32 mm ID</b> (0.5 mm OD)				
0.25 µm film	726777.25	726777.30	–	726777.60
1.00 µm film	–	726780.30	726780.50	726780.60
<b>0.53 mm ID</b> (0.8 mm OD)				
1.00 µm film	726783.25	–	–	–

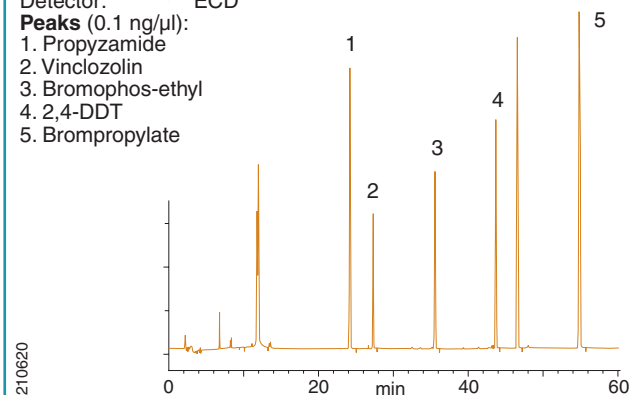
In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.

### Analysis of a pesticide mixture

Capillary column: OPTIMA® 1301, 0.25 µm film, 60 m x 0.25 mm ID, max. temperature 300/320 °C, Cat. No. 726 771.60  
 Injection: 3 µl, 80 °C (1 min) → 250°C (1 min), pulsed splitless  
 Carrier gas: He, 54 ml/min  
 Temperature: 80 °C (2 min) → 190 °C, 20 °C/min (12 min) → 240 °C, 2 °C/min (23 min) → 260°C, 10 °C/min (20 min)  
 ECD

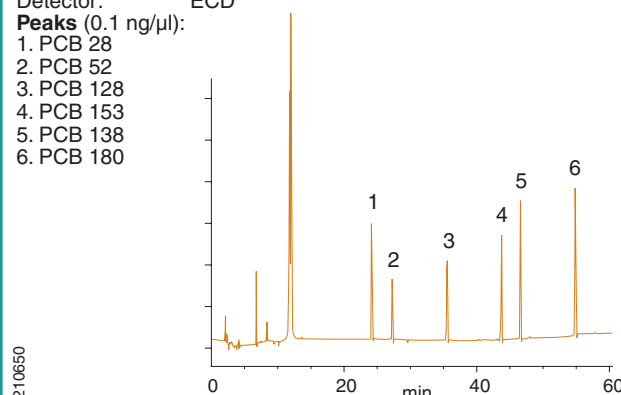
Detector: ECD  
 Peaks (0.1 ng/µl):  
 1. Propyzamide  
 2. Vinclozolin  
 3. Bromophos-ethyl  
 4. 2,4-DDT  
 5. Bromopropylate



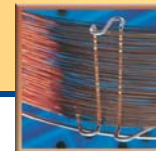
### Analysis of a PCB mixture

Capillary column: OPTIMA® 1301, 0.25 µm film, 60 m x 0.25 mm ID, max. temperature 300/320 °C, Cat. No. 726 771.60  
 Injection: 3 µl, 80 °C (1 min) → 250°C (1 min), pulsed splitless  
 Carrier gas: He, 54 ml/min  
 Temperature: 80 °C (2 min) → 190 °C, 20 °C/min (12 min) → 240 °C, 2 °C/min (23 min) → 260°C, 10 °C/min (20 min)  
 ECD

Detector: ECD  
 Peaks (0.1 ng/µl):  
 1. PCB 28  
 2. PCB 52  
 3. PCB 128  
 4. PCB 153  
 5. PCB 138  
 6. PCB 180



# Capillary columns for GC



## OPTIMA® high performance capillary columns

### Optima® 624

6% cyanopropyl-phenyl – 94% dimethylpolysiloxane

Max. temperature for isothermal operation 280 °C, max. temperature for short isotherms in a temperature programme 300 °C

- Medium polar
- Recommended for environmental analyses
- Similar phases: HP-624, HP-VOC, DB-624, DB-VRX, SPB-624, CP-624, RTX-624, RTX-Volatiles, 007-624, BP624, VOCOL
- USP G43

### Optima® 624 LB

6% cyanopropyl-phenyl – 94% dimethylpolysiloxane  
**Low Bleed**

- The excellent **Low Bleed** capillary columns for halogenated hydrocarbons, volatiles, aromatic compounds, solvents etc.

#### Solvents and semi-volatiles

Column: OPTIMA® 624 LB, 1.8 µm film, 30 m x 0.32 mm ID, Cat. No. 726786.30; retention gap Phe-Sil 0.5 m x 0.53 mm, Cat. No. 723711.10

Carrier gas: 1.1 bar He  
Temperature: 45 °C (3 min) → 150 °C (6 °C/min) → 300 °C (18 °C/min), 20 min 300 °C

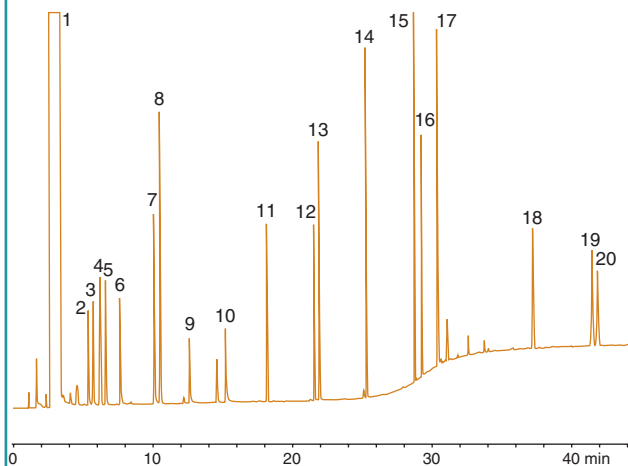
Injection: 1 µl, cold on-column

Detection: FID, 280 °C

Peaks: (10 ppm per substance in acetone)

- |                       |                                       |
|-----------------------|---------------------------------------|
| 1. Acetone            | 12. Octanol-1                         |
| 2. Ethyl acetate      | 13. Acetophenone                      |
| 3. Tetrahydrofuran    | 14. Butyrophenone                     |
| 4. Cyclohexane        | 15. Heptanophenone                    |
| 5. Methyl-2-butanol-2 | 16. Methoxy-5-indole                  |
| 6. Butanol-1          | 17. Dibenzylamine                     |
| 7. Pyridine           | 18. Methyl eicosanoate                |
| 8. Toluene            | 19. Methyl <i>cis</i> -13-docosenoate |
| 9. Dimethylformamide  | 20. Methyl docosanoate                |
| 10. Dimethylsulfoxide |                                       |
| 11. Decane            |                                       |

212520



Ordering information		Cat. No. for column length of			
		25 m	30 m	50 m	60 m
OPTIMA® 624	0.2 mm ID (0.4 mm OD)				
	1.10 µm film	726784.25	–	–	–
	0.25 mm ID (0.4 mm OD)				
	1.40 µm film	726785.25	726785.30	726785.50	726785.60
	0.32 mm ID (0.5 mm OD)				
	1.80 µm film	726787.25	726787.30	726787.50	726787.60
	0.53 mm ID (0.8 mm OD)				
	3.00 µm film	726789.25	726789.30	–	–
OPTIMA® 624 LB	0.32 mm ID (0.5 mm OD)				
	1.80 µm film	–	726786.30	726786.50	–

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

On request, all columns can be supplied on a 5 inch (13 cm) cage for the Agilent GC 6850. For ordering, please add an E at the end of the catalogue number (e.g. 726470.30E)

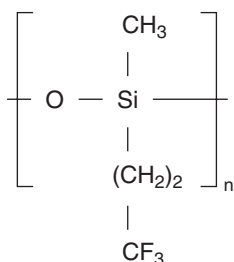


# Capillary columns for GC

## OPTIMA® high performance capillary columns

# Optima® 210

trifluoropropyl-methylpolysiloxane (50% trifluoropropyl)



Max. temperature for isothermal operation 260 °C, max. temperature for short isotherms in a temperature programme 280 °C

- Polar
- Recommended for environmental analyses, especially for *o*-, *m*- and *p*-substituted aromatic hydrocarbons
- Similar phases: OV-210, DB-210, Rtx-200, 007-210
- close equivalent to USP G6

### Aromatic hydrocarbons (BTX)

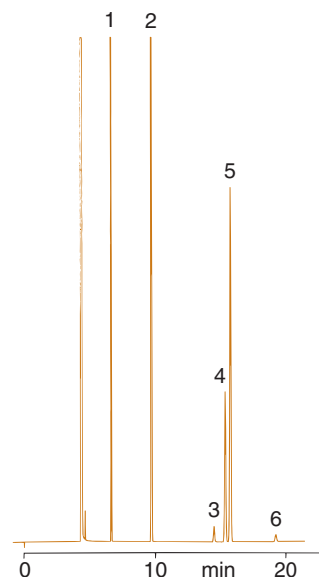
Capillary column: OPTIMA® 210, 0.5 µm film, 50 m x 0.25 mm ID, max. temperature 240/260 °C, Cat. No. 726874.50

#### Chromatographic conditions:

Injection volume: 0.5 µl  
 Carrier gas: 130 kPa N<sub>2</sub> (1.1 ml/min)  
 Split: 105 ml/min  
 Temperature: 50 °C  
 Detector: FID, 250 °C, 2<sup>6</sup>

#### Peaks:

1. Benzene
2. Toluene
3. Ethylbenzene
4. *p*-Xylene
5. *m*-Xylene
6. *o*-Xylene



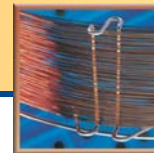
200230

Ordering information	Cat. No. for column length of				
	15 m	25 m	30 m	50 m	60 m
<b>0.25 mm ID (0.4 mm OD)</b>					
0.25 µm film	726871.15	726871.25	726871.30	726871.50	726871.60
0.50 µm film	–	–	726874.30	726874.50	726874.60
<b>0.32 mm ID (0.5 mm OD)</b>					
0.25 µm film	726877.15	–	726877.30	726877.50	726877.60
0.50 µm film	–	726880.25	726880.30	726880.50	726880.60

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.

# Capillary columns for GC

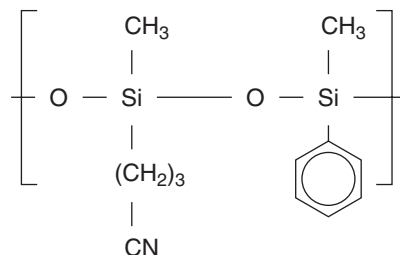


## OPTIMA® high performance capillary columns

# Optima® 225

- Max. temperature for isothermal operation 260 °C, max. temperature for short isotherms in a temperature programme 280 °C
- Polar
- Recommended for fatty acid analyses
- Similar phases: DB-225, HP-225, OV-225, Rtx-225, CP-SIL 43, 007-225, BP225
- close equivalent to USP G7

50% cyanopropyl-methyl – 50% phenylmethylpolysiloxane



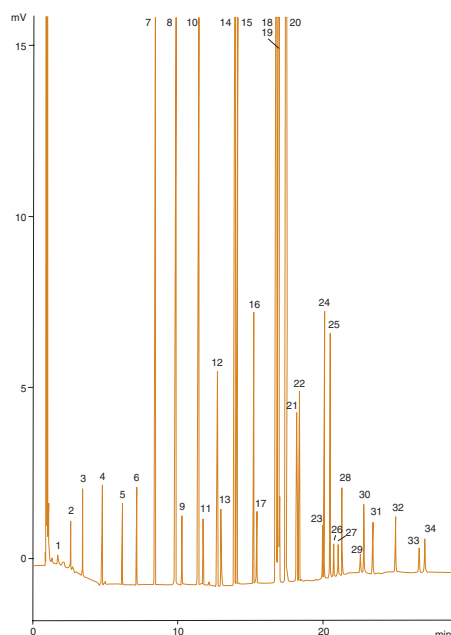
### Analysis of FAME in porcine fat

Column: OPTIMA® 225, 0.25 µm film, 25 m x 0.32 mm ID, max. temperature 260/280 °C, Cat. No. 726352.25  
 Injection volume: 1 µl, split 1:40; carrier gas 60 kPa H<sub>2</sub>  
 Temperature: 50 °C (2 min) → 125 °C, 30 °C/min → 160 °C, 5 °C/min → 180 °C, 20 °C/min → 200 °C, 3 °C/min → 220 °C, 20 °C/min (10 min)  
 Detector: FID 260 °C

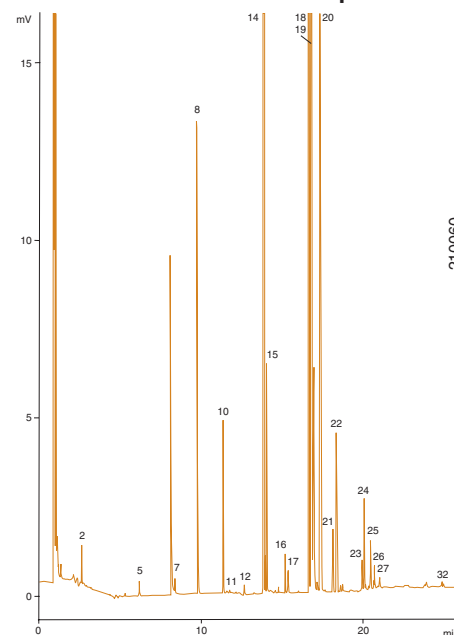
#### Peaks:

- |            |            |
|------------|------------|
| 1. C 4:0   | 18. C 18:0 |
| 2. C 5:0   | 19. C 18:1 |
| 3. C 6:0   | 20. C 18:2 |
| 4. C 8:0   | 21. C 18:3 |
| 5. C 10:0  | 22. C 19:0 |
| 6. C 11:0  | 23. C 20:0 |
| 7. C 12:0  | 24. C 20:1 |
| 8. C 13:0  | 25. C 20:2 |
| 9. C 13:1  | 26. C 20:4 |
| 10. C 14:0 | 27. C 20:3 |
| 11. C 14:1 | 28. C 20:5 |
| 12. C 15:0 | 29. C 22:0 |
| 13. C 15:1 | 30. C 22:1 |
| 14. C 16:0 | 31. C 22:2 |
| 15. C 16:1 | 32. C 22:6 |
| 16. C 17:0 | 33. C 24:0 |
| 17. C 17:1 | 34. C 24:1 |

#### FAME standard



#### FAME in porcine fat



Chromatograms courtesy of  
 Dr. Bantleon, Mr. Leusche,  
 Mr. Hagemann, VFG-Labor,  
 Versmold, Germany

Ordering information	Cat. No. for column length of					
	10 m	15 m	25 m	30 m	50 m	60 m
<b>0.10 mm ID (0.4 mm OD)</b>						
0.10 µm film	726080.10	–	–	–	–	–
<b>0.25 mm ID (0.4 mm OD)</b>						
0.25 µm film		726118.15	726118.25	726118.30	726118.50	726118.60
<b>0.32 mm ID (0.5 mm OD)</b>						
0.25 µm film		–	726352.25	726352.30	726352.50	726352.60

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

On request, all columns can be supplied on a 5 inch (13 cm) cage for the Agilent GC 6850. For ordering, please add an E at the end of the catalogue number (e.g. 726470.30E)



# Capillary columns for GC

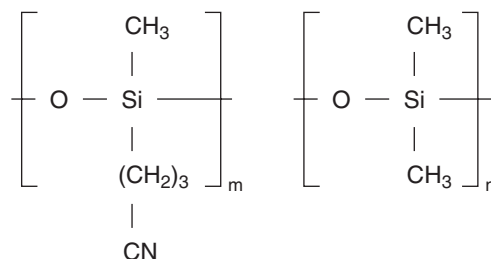
## OPTIMA® high performance capillary columns

# Optima® 240

No similar phases

- Max. temperature for isothermal operation 260 °C, max. temperature for short isotherms in a temperature programme 280 °C
- Highly polar
- Recommended for FAMEs, dioxins

33% cyanopropyl-methyl – 67% dimethylpolysiloxane



### Fatty acid methyl esters cis/trans C 18:1 (FAME)

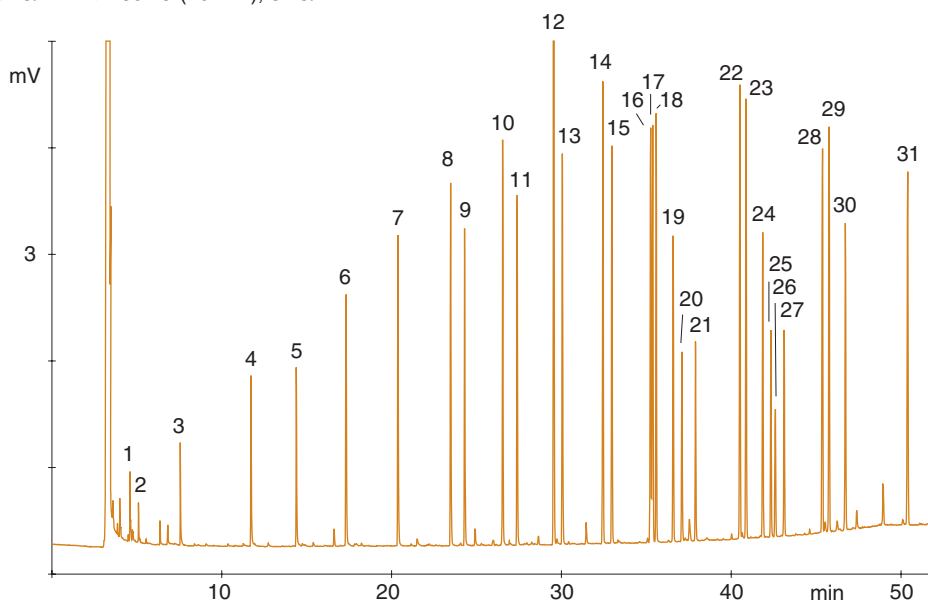
Capillary column: OPTIMA® 240, 0.25 film, 60 m x 0.25 mm ID, max. temperature 260/280 °C, Cat. No. 726089.60

#### Chromatographic conditions:

Sample: FAME mixture  
 Injection volume: 1.0 µl, split 1 : 25  
 Carrier gas: 150 kPa H<sub>2</sub>  
 Temperature: 80 °C → 120 °C, 20 °C/min → 260 °C (10 min), 3 °C/min  
 Detector: FID, 280 °C

#### Peaks:

- |                  |                |
|------------------|----------------|
| 1. C 4:0         | 18. cis-C 18:1 |
| 2. C 5:0         | 19. C 18:2     |
| 3. C 8:0         | 20. C 18:3     |
| 4. C 10:0        | 21. C 18:3     |
| 5. C 11:0        | 22. C 20:0     |
| 6. C 12:0        | 23. C 20:1     |
| 7. C 13:0        | 24. C 20:2     |
| 8. C 14:0        | 25. C 20:3     |
| 9. C 14:1        | 26. C 20:4     |
| 10. C 15:0       | 27. C 20:3     |
| 11. C 15:1       | 28. C 22:0     |
| 12. C 16:0       | 29. C 22:1     |
| 13. C 16:1       | 30. C 22:3     |
| 14. C 17:0       | 31. C 24:1     |
| 15. C 17:1       |                |
| 16. C 18:0       |                |
| 17. trans-C 18:1 |                |



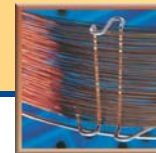
201620

Ordering information	Cat. No. for column length of			
	25 m	30 m	50 m	60 m
<b>0.25 mm ID (0.4 mm OD)</b>				
0.25 µm film	–	726089.30	726089.50	726089.60
0.50 µm film	–	726090.30	–	726090.60
<b>0.32 mm ID (0.5 mm OD)</b>				
0.25 µm film	726091.25	726091.30	726091.50	726091.60
0.35 µm film	–	726095.30	–	726095.60
0.50 µm film	–	726096.30	–	726096.60

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.

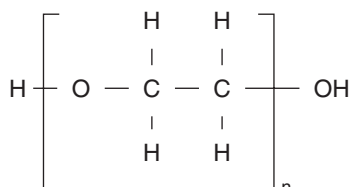
# Capillary columns for GC



## OPTIMA® high performance capillary columns

# Optima® WAX

polyethylene glycol 20000 dalton



For columns with 0.25 – 0.32 mm ID the max. temperature for isothermal operation is 250 °C, the max. temperature for short isotherms in a temperature programme is 260 °C  
for 0.53 mm ID columns the max. temperatures are 220 and 240 °C, resp.

- polar
- recommended for solvent analysis and alcohols
- suitable for aqueous solutions
- similar phases: DB-Wax, Supelcowax, HP-Wax, HP-INNOWAX, Rtx-Wax, CP-Wax 52 CB, Stabilwax, 007-CW, BP20, AT-Wax, ZB-Wax
- USP G16

### Grob test

Capillary column: OPTIMA® WAX, 0.5 µm film, 50 m x 0.32 mm ID, max. temperature 250/260 °C, Cat. No. 726296.50

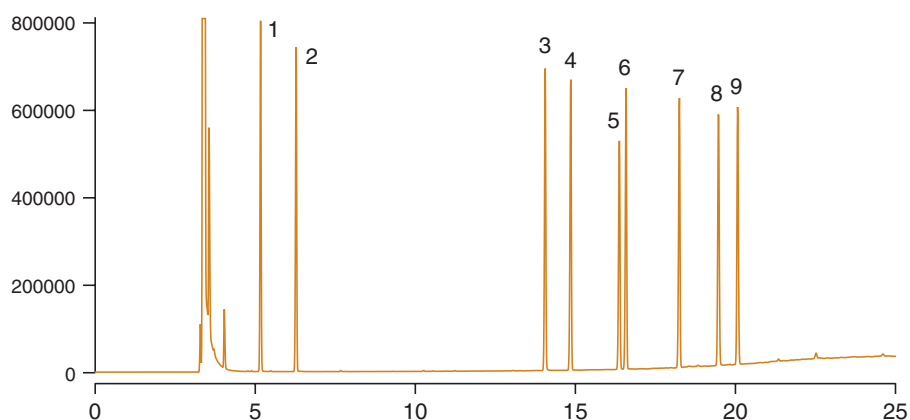
#### Chromatographic conditions:

Injection volume: 1 µl  
Carrier gas: 1.2 bar He  
Split: 1:20  
Temperature: 80 °C → 250 °C,  
8 °C/min

Detector: FID, 250 °C

#### Peaks:

1. Decane
2. Undecane
3. Octanol
4. Methyl decanoate
5. Dicyclohexylamine
6. Methyl undecanoate
7. Methyl dodecanoate
8. 2,6-Dimethylaniline
9. 2,6-Dimethylphenol



Ordering information	Cat. No. for a column length of			
	25 m	30 m	50 m	60 m
<b>0.25 mm ID (0.4 mm OD)</b>				
0.25 µm film	726600.25	726600.30	726600.50	726600.60
<b>0.32 mm ID (0.5 mm OD)</b>				
0.25 µm film	726321.25	726321.30	726321.50	726321.60
0.50 µm film	726296.25	726296.30	726296.50	726296.60
<b>0.53 mm ID (0.8 mm OD)</b>				
1.00 µm film	726549.25	726549.30	–	–
2.00 µm film	–	726548.30	–	–

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

On request, all columns can be supplied on a 5 inch (13 cm) cage for the Agilent GC 6850. For ordering, please add an E at the end of the catalogue number (e.g. 726470.30E)



# Capillary columns for GC

## OPTIMA® high performance capillary columns

# Optima® FFAP

polyethylene glycol 2-nitroterephthalate

For columns with 0.10 – 0.32 mm ID the max. temperature for isothermal operation is 250 °C, the max. temperature for short isotherms in a temperature programme is 260 °C  
for 0.53 mm ID columns the max. temperatures are 220 and 240 °C, resp.

- polar
- recommended for FAMES, free carboxylic acids
- similar phases: DB-FFAP, HP-FFAP, CP-SIL 58 CB, 007-FFAP, CP-FFAP CB, Nukol
- close equivalent to USP G35

### FAME test

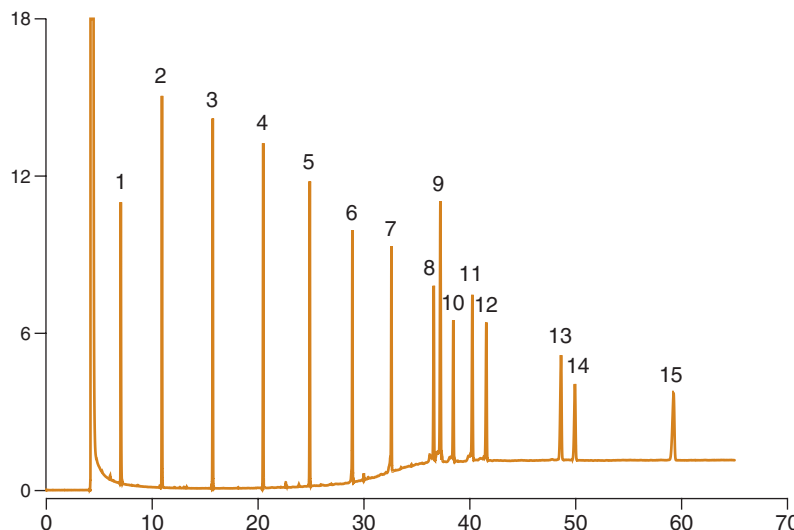
Capillary column: OPTIMA® FFAP, 0.25 µm film, 60 m x 0.32 mm ID, max. temperature 250/260 °C, Cat. No. 726341.60

#### Chromatographic conditions:

Carrier gas: 1,2 bar He, split  
Temperature: 55 °C → 250 °C, 6 °C/min  
Injector: 220 °C  
Detector: 220 °C

#### Peaks:

1. C4
2. C6
3. C8
4. C10
5. C12
6. C14
7. C16
8. C18
9. C18:1 c/t
10. C18:2
11. C18:3
12. C20
13. C22
14. C22:1
15. C24



211140

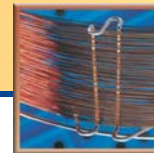
Ordering information	Cat. No. for a column length of				
	10 m	25 m	30 m	50 m	60 m
<b>0.10 mm ID</b> (0.4 mm OD)					
0.10 µm film	<b>726180.10</b>	–	–	–	–
<b>0.25 mm ID</b> (0.4 mm OD)					
0.25 µm film	–	<b>726116.25</b>	<b>726116.30</b>	<b>726116.50</b>	<b>726116.60</b>
<b>0.32 mm ID</b> (0.5 mm OD)					
0.25 µm film	–	<b>726341.25</b>	<b>726341.30</b>	<b>726341.50</b>	<b>726341.60</b>
0.50 µm film	–	<b>726344.25</b>	<b>726344.30</b>	<b>726344.50</b>	–
<b>0.53 mm ID</b> (0.8 mm OD)					
0.50 µm film	–	–	<b>726345.30</b>	–	–
1.00 µm film	–	<b>726346.25</b>	–	–	–

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.



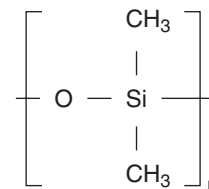
# Capillary columns for GC




## PERMABOND® capillary columns

### PERMABOND® SE-30

100% dimethylpolysiloxane



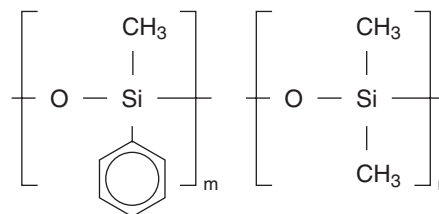
 Max. temperature for isothermal operation 300 °C, max. temperature for short isotherms in a temperature programme 320 °C


Ordering information	Cat. No. for column length of		
	10 m	25 m	50 m
<b>0.25 mm ID (0.4 mm OD)</b>			
0.25 µm film	–	<b>723052.25</b>	<b>723052.50</b>
<b>0.32 mm ID (0.5 mm OD)</b>			
0.25 µm film	–	<b>723306.25</b>	<b>723306.50</b>
0.50 µm film	<b>723308.10</b>	<b>723308.25</b>	<b>723308.50</b>

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

### PERMABOND® SE-52

5% phenyl – 95% dimethylpolysiloxane



 Max. temperature for isothermal operation 300 °C, max. temperature for short isotherms in a temperature programme 320 °C

Ordering information	Cat. No. for column length of	
	25 m	50 m
<b>0.25 mm ID (0.4 mm OD)</b>		
0.25 µm film	<b>723054.25</b>	<b>723054.50</b>
<b>0.32 mm ID (0.5 mm OD)</b>		
0.25 µm film	<b>723310.25</b>	–
0.50 µm film	<b>723312.25</b>	<b>723312.50</b>

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.

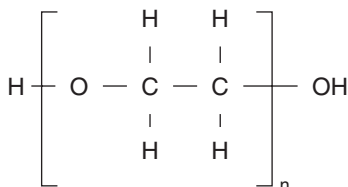


# Capillary columns for GC

## PERMABOND® capillary columns

### PERMABOND® CW 20 M

polyethylene glycol  
20000 dalton



- 0.1 – 0.32 mm ID: max. temperature for isothermal operation 220 °C, max. temperature for short isotherms in a temperature programme 240 °C  
0.53 mm ID: max temperatures 200 and 220 °C, resp.
- Polar
  - Recommended for solvent analyses and alcohols
  - Suitable for aqueous solutions
  - Similar phases see OPTIMA® WAX page 335
  - USP G16

Ordering information	Cat. No. for column length of				
	10 m	25 m	30 m	50 m	60 m
<b>0.1 mm ID (0.4 mm OD)</b> 0.10 µm Film	<b>723064.10</b>	–	–	–	–
<b>0.25 mm ID (0.4 mm OD)</b> 0.25 µm film	<b>723060.10</b>	<b>723060.25</b>	<b>723060.30</b>	<b>723060.50</b>	<b>723060.60</b>
<b>0.32 mm ID (0.5 mm OD)</b> 0.25 µm film	<b>723321.10</b>	<b>723321.25</b>	<b>723321.30</b>	<b>723321.50</b>	<b>723321.60</b>
0.35 µm film	<b>723827.10</b>	<b>723827.25</b>	–	<b>723827.50</b>	–
0.50 µm film	<b>723296.10</b>	<b>723296.25</b>	<b>723296.30</b>	<b>723296.50</b>	<b>723296.60</b>
<b>0.53 mm ID (0.8 mm OD)</b> 0.50 µm film	<b>723515.10</b>	<b>723515.25</b>	–	–	–
1.00 µm film	<b>723549.10</b>	<b>723549.25</b>	<b>723549.30</b>	–	–
2.00 µm film	<b>723517.10</b>	<b>723517.25</b>	<b>723517.30</b>	–	–

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

### PERMABOND® FFAP

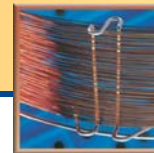
polyethylene glycol 2-nitroterephthalic acid ester

- 0.1 – 0.32 mm ID: max. temperature for isothermal operation 220 °C, max. temperature for short isotherms in a temperature programme 240 °C  
0.53 mm ID: max temperatures 200 and 220 °C, resp.
- Polar
  - Recommended for FAMES, free carboxylic acids
  - Similar phases see OPTIMA® FFAP page 336

Ordering information	Cat. No. for column length of					
	10 m	20 m	25 m	30 m	50 m	60 m
<b>0.1 mm ID (0.4 mm OD)</b> 0.10 µm Film	<b>723180.10</b>	<b>723180.20</b>	–	–	–	–
0.25 µm Film	<b>723181.10</b>	–	–	–	–	–
<b>0.25 mm ID (0.4 mm OD)</b> 0.10 µm film	–	–	<b>723936.25</b>	–	<b>723936.50</b>	–
0.25 µm film	<b>723116.10</b>	–	<b>723116.25</b>	<b>723116.30</b>	<b>723116.50</b>	<b>723116.60</b>
<b>0.32 mm ID (0.5 mm OD)</b> 0.10 µm film	–	–	<b>723356.25</b>	–	<b>723356.50</b>	–
0.25 µm film	–	–	<b>723341.25</b>	<b>723341.30</b>	<b>723341.50</b>	<b>723341.60</b>
0.35 µm film	<b>723830.10</b>	–	<b>723830.25</b>	–	<b>723830.50</b>	–
0.50 µm film	<b>723344.10</b>	–	<b>723344.25</b>	<b>723344.30</b>	<b>723344.50</b>	<b>723344.60</b>
<b>0.53 mm ID (0.8 mm OD)</b> 1.00 µm film	<b>723555.10</b>	–	<b>723555.25</b>	–	<b>723555.50</b>	–

In addition to this standard programme we will be happy to supply columns custom-made to your specifications.

Each column is individually tested and supplied with test certificate and test chromatogram, but without fittings or ferrules. Column ends are closed with septa, and thus protected from atmospheric oxygen. Additionally, we supply the corresponding test mixture with each column.



## OPTIMA® and PERMABOND® capillary columns

### Important hints for use and maintenance of capillary columns

#### Oxygen-free carrier gas

Generally, use of oxygen-free carrier gas is recommended for all stationary phases, however, it is of vital importance for the phases Carbowax 20M and FFAP, which are easily oxidised by traces of air. Remove the oxygen by passing the carrier gas through an oxygen absorber cartridge (e.g. Oxisorb® cartridge, see page 374), which should be exchanged before it is completely exhausted.

Lifetime of a column can also be increased, if you do not exceed the temperature limits indicated for each phase. If you have any difficulties with your new MN column, please contact us immediately, before the column is damaged or even rendered worthless by improper handling.

#### Flushing of capillary columns with immobilised phases

Immobilisation of a phase in a capillary column allows removal of contaminations by flushing with solvents. For **flushing** we recommend the "inert" solvents usually applied for dissolving samples, such as e.g. methanol, methylene chloride, alkanes like pentane or aromatics like toluene. Aggressive substances, e.g. trifluoroacetic acid, chlorosilanes or alkalis etc. are not to be used. After flushing the column should be dried with carrier gas at room temperature and heated to the maximum allowed temperature (see certificate) with a slow temperature programme (about 2 °C/min). For our flushing unit for capillary columns with chemically bonded phases, please see our range of capillary accessories on page 369.

#### Storage and conditioning

If capillary columns are not used for an extended period of time, they should be stored closed and protected from light (FFAP, CW 20 M and Wax).

Prior to use capillary columns (especially with immobilised phases) should be conditioned for several hours, ideally over

night, because basic substances, such as dicyclohexylamine from Grob test mixture, can be absorbed partially or even completely.

#### Procedure for column conditioning

(described here for an OPTIMA® 1 column with 0.25 µm film, 25 m length and 0.25 mm ID):

- Install the column in the chromatograph observing the safety precautions
- Heat the column from ambient temperature to the maximum temperature allowed for **isothermal** operation (first temperature in our descriptions, **in this case** 340 °C) with about 2 °C/min using a carrier gas pressure of 0.5 bar

- Leave the column at this temperature **over night**

As an alternative, you may use the following procedure:

- Apply a temperature programme with a heating rate of 10 °C/min from 60 °C to the maximum temperature allowed for **temperature programmes** (second temperature in our descriptions, **in this case** 360 °C) and repeat it at least three times (better 5 times)

After these procedures the test chromatogram with the MN OPTIMA® test mixture (Cat. No. 722313) should be reproduced.

**Attention!** When using **ECD** or **MS** detection or for columns with a film thickness  $\geq 1 \mu\text{m}$  the column should be **separated from the detector during conditioning**.

During conditioning the long-time maximum temperature must never be exceeded. Also make sure that the gas supply is not interrupted. Without carrier gas any stationary phase is rapidly destroyed at high temperatures.

## GC capillary columns for special applications · Summary

Instead of using standard columns, certain analytical separation tasks can be performed more easily with chromatographic columns, which have been especially developed for

the respective problem. The following table summarises our programme of GC speciality capillaries, the individual column types are described in detail on the following pages.

Separation problem / preferred application	Recommended capillary column	Page	
<b>Fast GC</b>	OPTIMA® δ-3, OPTIMA® δ-6 OPTIMA® 1, OPTIMA® 5, OPTIMA® 17, OPTIMA® 225, OPTIMA® FFAP PERMABOND® CW 20 M, FFAP all 0.10 mm ID	340	
<b>Amines</b>	especially for polyfunctional amines basic for amine separations	OPTIMA® 5 Amine FS-CW 20 M-AM	342
<b>Volatile substances</b>	solvent analyses for analytes in an aqueous matrix	OPTIMA® 1 thick film columns ( $\geq 3 \mu\text{m}$ film) OPTIMA® 5 thick film columns ( $\geq 3 \mu\text{m}$ film) OPTIMA® 624	324 326 331
<b>Petrochemical products</b> (complex hydrocarbon mixtures)	PERMABOND® P-100	343	



# Capillary columns for GC

## GC capillary columns for special applications · Summary

Separation problem / preferred application		Recommended capillary column	Page
<b>Environmental analyses</b>	volatile halogenated hydrocarbons PAH, PCB, pesticides, dioxins etc.	PERMABOND® SE-54 HKW	344
		OPTIMA® 1, OPTIMA® 1 MS	324
		OPTIMA® 5, OPTIMA® 5 MS	326
		OPTIMA® δ-3	322
		OPTIMA® δ-6	323
<b>Triglycerides</b>		OPTIMA® 1-TG OPTIMA® 17-TG	345
<b>Silanes</b> (monomeric, e.g. chlorosilanes)		PERMABOND® Silane	346
<b>Diethylene glycol</b> , e.g. for the quality control of wine		PERMABOND® CW 20 M-DEG	346
<b>Enantiomer separation</b>	cyclodextrin phases	FS-LIPODEX® A, FS-LIPODEX® B FS-LIPODEX® C, FS-LIPODEX® D FS-LIPODEX® E, FS-LIPODEX® G	347
		FS-HYDRODEX β-PM FS-HYDRODEX β-3 P FS-HYDRODEX β-6TBDM FS-HYDRODEX β-TBDAC	
	diamide type chiral polysiloxane	PERMABOND® L-CHIRASIL-VAL	351

### Fast GC columns

Efficiency in a laboratory is more and more determined by the sample throughput. The higher the number of samples per time unit run on an instrument, the higher is the productivity of the system. In industrial and commercial laboratories high sample numbers are the rule. It is of high priority to obtain results as fast as possible. Since, for conventional standard analyses the analytical cycle (total measuring and cooling time) is 10 to 60 minutes, depending on the number of components, productivity is limited by the high time requirements. Thus it is necessary to shorten the analytical cycle in order to reach a higher sample throughput.

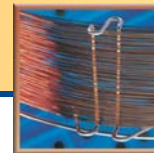
State-of-the-art instrumentation, and recent column development meet this demand with terms like high-speed GC, fast GC, very fast GC, ultra-fast GC. These stand for different approaches and techniques, which have been developed during the past years to obtain faster GC separations, without loss of resolution. Apart from simultaneous decrease of column diameter and length, efforts center on temperature-programmed GC with extremely high heating rates, a sharp focussing of the injected sample and high flow rates.

Use of a column with smaller inner diameter combined with very fast temperature programmes can reduce the analysis time by up to 80%, if the injection technique, and also the detection and data acquisition speed are suited for this method. The amount of sample, which can be injected, is of course limited by the inner diameter of the column and the thin film. It is important to find the optimum between fast

chromatography and the resolution required. A reduction of the inner diameter is related to a higher column inlet pressure (head pressures of up to 10 bar), and a lower volume flow of the mobile phase, as well as smaller peak widths and sample capacities. This requires the very fast injection of very small sample volumes against a high pressure. High sensitivity detectors with small volume and extremely short response time, as well as a very rapid data acquisition, and processing are required. If using e.g. a mass spectrometer for the evaluation of data, scan rates of up to 6750 dalton/s are necessary to obtain sufficient data points for integration. Stationary phases for fast GC have to meet special demands due to the high heating rates applied. It is necessary to use specially bonded phases in order to prevent column bleeding. The manufacturing process of the OPTIMA® columns meets exactly this requirement. OPTIMA® columns show very low bleeding and provide long lifetimes, even when continuously subjected to high heating rates.

#### References

- C. A. Cramers et al., J. Chromatogr. **856** (1999) 315 – 329  
C. A. Cramers et al., J. Chromatogr. **842** (1999) 3 – 13



## GC capillary columns for special applications · Fast GC

### Comparison of a separation on a 50 m standard capillary with separation on a 10 m fast GC column

#### A) Fast GC column

Column: OPTIMA® 5, 0.1 µm film, 10 m x 0.1 mm ID,  
max. temperature 340/360 °C, Cat. No. 726846.10  
injection 1 µl, split 1 : 40, carrier gas 0.75 bar He

#### B) standard GC column

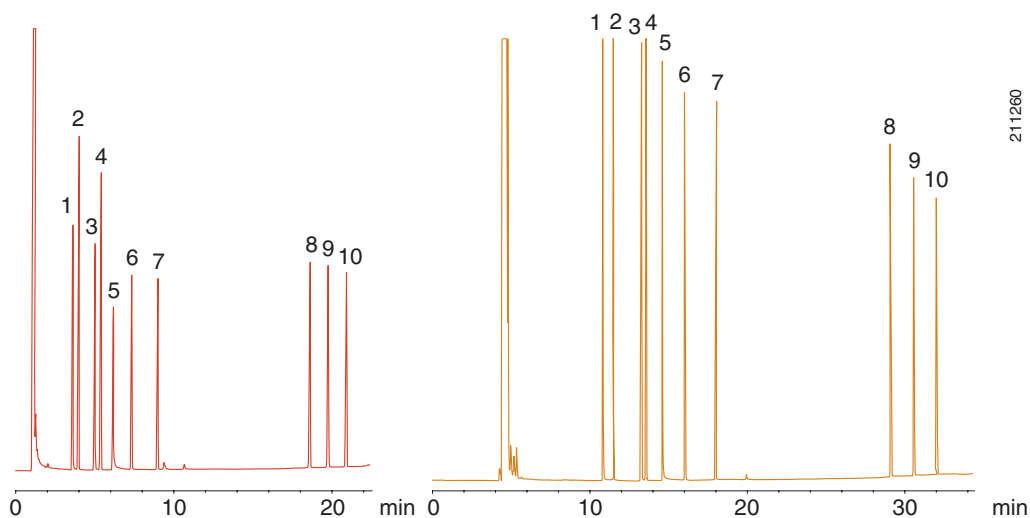
Column: OPTIMA® 5, 0.25 µm film, 50 x 0.25 mm ID,  
max. temperature 340/360 °C, Cat. No. 726056.50  
injektion 1 µl, split 1 : 35, carrier gas 1.5 bar He

both separations: temperature: 80 °C → 320 °C (10 min), 8 °C/min, detector: FID

While maintaining the temperature programme and halving the pressure a **time saving of 30%** results with **identical separation efficiency**

#### Peaks:

1. Octanol
2. Undecane
3. Dimethylaniline
4. Dodecane
5. Decylamine
6. Methyl decanoate
7. Methyl undecanoate
8. Henicosane
9. Docosane
10. Tricosane



### Columns for fast GC

### Ordering information

Phase	max. temperature	ID [mm]	film thickness [µm]	Cat. No. (10 m)	Cat. No. (20 m)
OPTIMA® δ-3	340/360 °C	0.10	0.10	726410.10	726410.20
OPTIMA® δ-6	340/360 °C	0.10	0.10	726490.10	–
OPTIMA® 1	340/360 °C	0.10	0.10	726024.10	726024.20
		0.10	0.40	–	726025.20
OPTIMA® 5	340/360 °C	0.10	0.10	726846.10	–
OPTIMA® 17	320/340 °C	0.10	0.10	726848.10	–
OPTIMA® 225	260/280 °C	0.10	0.10	726080.10	–
OPTIMA® FFAP	250/260 °C	0.10	0.10	726180.10	–
PERMABOND® CW 20 M	220/240 °C	0.10	0.10	723064.10	–
PERMABOND® FFAP	220/240 °C	0.10	0.10	723180.10	723180.20
		0.10	0.25	723181.10	–
OPTIMA® 5 Amin	300/320 °C	0.10	0.40	726361.10	–
FS-CW 20 M-AM	220/240 °C	0.10	0.20	733111.10	–
FS-LIPODEX® E	200/220 °C	0.10	0.10	723382.10	–
FS-HYDRODEX β-6TBDM	230/250 °C	0.10	0.10	723383.10	–



# Capillary columns for GC

## GC capillary columns for special applications · amine separations

### OPTIMA® 5 Amine – the special column for the analysis of amines

The columns OPTIMA® 5 Amine have especially been developed for the analysis of polyfunctional amines such as e.g. ethanolamines, amino-functionalised diols and similar compounds. This group of substances, which are important basic materials in industrial chemistry, shows strong tailing on standard-deactivated columns. The OPTIMA® 5 Amine, however, is deactivated with a special procedure, which enables the chromatography of these critical compounds. OPTIMA® 5 Amine columns also feature an improved linearity for the determination of active components at trace levels: thus even for aliphatic and aromatic amines at concentrations of 100 pg/peak they show practically no amine absorptions.

All OPTIMA® 5 Amine columns are tested with the OPTIMA® Amine test mixture (Cat. No. 722317), which among others also contains diethanolamine and propanol-pyridine. This test mixture is supplied with each column.

● Similar phases: RTX Amine, PTA-5

### FS-CW 20 M-AM

#### Polyethylene glycol 20000

These are non-immobilised capillary columns based on polyethylene glycol, basic for amine separations.

● Similar phases: Carbowax Amine, CP-Wax 51, CAM, Stabilwax DB

### Separation of secondary and tertiary amines

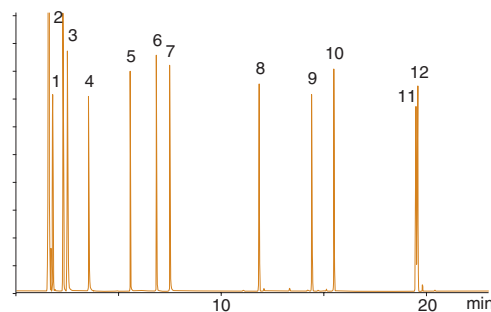
Capillary column: OPTIMA® 5 Amine, 0.5 µm film, 30 m x 0.25 mm ID, max. temp. 300/320 °C, Cat. No. 726354.30

#### Chromatographic conditions:

Injection volume: 1 µl  
 Carrier gas: 0.6 bar H<sub>2</sub>, split 1:100  
 Temperature: 100 °C (3 min) → 280 °C, 10 °C/min  
 Detector: FID, 280 °C

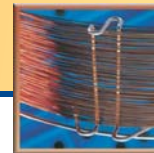
#### Peaks:

- |                               |                               |
|-------------------------------|-------------------------------|
| 1. Diethylamine               | 7. Di-isobutylamine           |
| 2. Di-isopropylamine          | 8. Tri- <i>n</i> -butylamine  |
| 3. Triethylamine              | 9. Di-isohexylamine           |
| 4. Di- <i>n</i> -propylamine  | 10. Dicyclohexylamine         |
| 5. Di- <i>n</i> -butylamine   | 11. Dibenzylamine             |
| 6. Tri- <i>n</i> -propylamine | 12. Tri- <i>n</i> -hexylamine |



210280

Ordering information	Cat. No. for column length of			
	10 m	25 m	30 m	50 m
<b>OPTIMA® 5 Amine, OPTIMA® 5 with special deactivation, tested with critical amines, max. temp. 300/320 °C</b>				
<b>0.1 mm ID (0.4 mm OD)</b>				
0.40 µm film	<b>726361.10</b>	–	–	–
<b>0.2 mm ID (0.4 mm OD)</b>				
0.35 µm film	–	<b>726355.25</b>	–	–
<b>0.25 mm ID (0.4 mm OD)</b>				
0.50 µm film	–	–	<b>726354.30</b>	–
1.00 µm film	–	–	<b>726358.30</b>	–
<b>0.32 mm ID (0.5 mm OD)</b>				
0.25 µm film	–	–	<b>726360.30</b>	–
1.00 µm film	–	–	<b>726353.30</b>	–
1.50 µm film	–	–	<b>726356.30</b>	–
<b>0.53 mm ID (0.8 mm OD)</b>				
1.00 µm film	–	–	<b>726359.30</b>	–
3.00 µm film	–	–	<b>726357.30</b>	–
<b>Capillary columns FS-CW 20 M-AM, basic for amine separations, max. temp. 220/240 °C</b>				
<b>0.1 mm ID (0.4 mm OD)</b>				
0.20 µm film	<b>733111.10</b>	–	–	–
<b>0.25 mm ID (0.4 mm OD)</b>				
0.25 µm film	–	<b>733110.25</b>	–	<b>733110.50</b>
<b>0.32 mm ID (0.5 mm OD)</b>				
0.25 µm film	–	<b>733299.25</b>	–	<b>733299.50</b>
0.35 µm film	–	–	–	<b>733442.50</b>
<b>0.53 mm ID (0.8 mm OD)</b>				
1.00 µm film	–	<b>733551.25</b>	–	–



## GC capillary columns for special applications · petrochemical products

### Capillary columns with thick films

Chromatography of highly volatile substances requires a thick film of stationary phase. The increased retention raises elution temperatures far above room temperature, thus avoiding costly cooling of the chromatograph below ambient temperature (see lower figure on page 317). Furthermore, problems caused by aqueous solutions on nonpolar stationary phases are reduced or completely avoided. The increase in film thickness results in a very high capacity and inertness. This is especially useful for samples with widely differing concentrations, or for the separation of volatile polar substances as shown in the chromatogram on the right.

Extremely active substrates present a special situation. In most cases such substances cause noticeable tailing, if they come in contact with uncoated spots of the column wall. These interactions can be reduced by use of short columns with thick films. This means a better coverage of the column wall by the thicker film and a reduction of the column surface due to the reduced length.

However, thick films also mean more phase in the column, and consequently higher bleeding. This results in lower maximum operating temperatures for thick film columns. In addition, thick film columns may have a lower efficiency.

#### Alcohols in methylene chloride

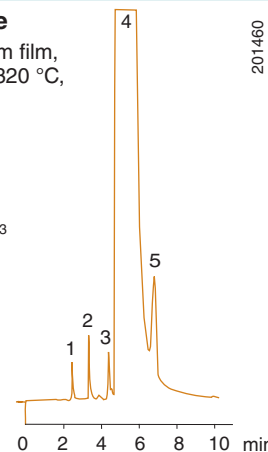
Capillary column: OPTIMA® 5, 5,0 µm film,  
25 m x 0.32 mm ID, max. temp. 300/320 °C,  
Cat. No. 726934.25

#### Chromatographic conditions:

Injection volume: 2 µl  
Carrier gas: 1 bar N<sub>2</sub>  
Split: 30 ml/min  
Temperature: 60 °C  
Detector: FID, 240 °C, 2<sup>3</sup>

#### Peaks:

1. Methanol
2. Ethanol
3. *i*-Propanol
4. Methylene chloride
5. Propanol



For ordering information see pages 324 and 326.

### Capillary columns for the GC analysis of petrochemical products

The analysis of complex mixtures of hydrocarbons requires a column with high resolution (e.g. for the separation of *m*- and *p*-xylene) and sufficient capacity, combined with a nonpolar stationary phase with a film thickness, which is not too high.

Our 100 m capillary column PERMABOND® P-100, which is coated with dimethylpolysiloxane (0.5 µm film thickness and 0.25 mm ID), meets these requirements. The chromatogram of unleaded gasoline show the performance of the column.

<b>Ordering information</b>	<b>Cat. No. for column length of</b>
	100 m
<b>PERMABOND® P-100 for petrochemical analyses</b>	
<b>dimethylpolysiloxane</b>	
max. temperature for isothermal operation 300 °C, max. temperature for short isotherms in a temperature programme 320 °C	
<b>0.25 mm ID (0.4 mm OD)</b>	
0.50 µm film	<b>723890.100</b>



# Capillary columns for GC

## GC capillary columns for special applications · environmental analyses

### Volatiles halogenated hydrocarbons

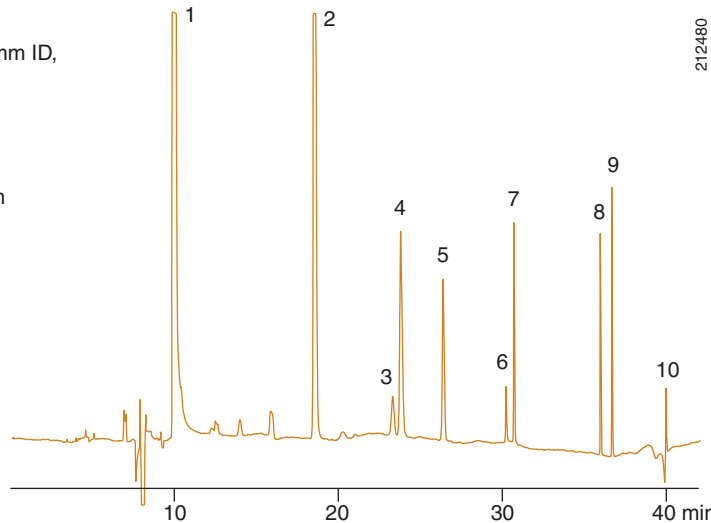
Capillary column: PERMABOND® SE-54-HKW, 50 m x 0.32 mm ID, max. temperature 300 °C, Cat. No. 723945.50

#### Chromatographic conditions:

Injection volume: 1 µl  
 Carrier gas: 0.9 bar He  
 Split: about 1:30  
 Temperature: 35 °C (25 min) → 160 °C (5 min), 10 °C/min  
 Detector: ECD, 300 °C

#### Peaks:

1. Dichloromethane (795 ng/ml)
2. Chloroform (75 ng/ml)
3. 1,1,1-Trichloroethane (67 ng/ml)
4. 1,2-Dichloroethane (100 ng/ml)
5. Carbon tetrachloride (15.9 ng/ml)
6. Trichloroethylene (14.6 ng/ml)
7. Bromodichloromethane (20 ng/ml)
8. Dibromochloromethane (122 ng/ml)
9. Tetrachloroethylene (81 ng/ml)
10. Bromoform (28.9 ng/ml)



212480

Our capillaries OPTIMA® 1 and OPTIMA® 5 have proven their outstanding performance for the GC analysis of PAH, pesticides, PCB, dioxin screening and similar separation problems. For confirming analytical results, especially for complex samples, phases OPTIMA® 17 or OPTIMA® 1701 are used. For the analysis of halogenated hydrocarbons we have optimised the parameters for our columns with the well-known polysiloxane phase SE-54 and offer the special column PERMABOND® SE-54 HKW with 25 or 50 m length. As an alternative and for confirming the analytical results for

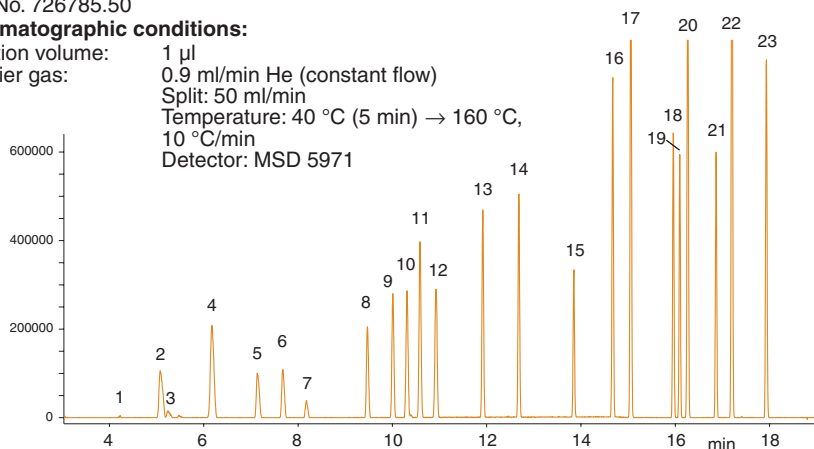
halogenated hydrocarbons, we recommend the column OPTIMA® 624, which shows advantages especially for the determination of 1,1,2-trichlorotrifluoroethane (F 113) besides dichloromethane. Both phases are also suited for determination of vinyl chloride and separation of *cis/trans*-1,2-dichloroethene. Thanks to the high capacity which results from the high film thickness, these columns show an outstanding resolution. For GC-MS coupling we recommend the phase OPTIMA® 624 LB or OPTIMA® 624 with 0.2 or 0.25 mm ID.

### Volatiles halogenated hydrocarbons and BTX

Capillary column: OPTIMA® 624, 50 m x 0.25 mm ID, max. temperature 260 °C, Cat. No. 726785.50

#### Chromatographic conditions:

Injection volume: 1 µl  
 Carrier gas: 0.9 ml/min He (constant flow)  
 Split: 50 ml/min  
 Temperature: 40 °C (5 min) → 160 °C, 10 °C/min  
 Detector: MSD 5971



#### Peaks:

1. Vinyl chloride
2. Trichlorofluoromethane (F 11)
3. Pentane
4. 1,1,2-Trichlorotrifluoroethane (F 113)
5. Dichloromethane
6. *trans*-1,2-Dichloroethene
7. Hexane
8. *cis*-1,2-Dichloroethene
9. Trichloromethane
10. 1,1,1-Trichloroethane
11. Tetrachloromethane
12. 1,2-Dichloroethane + benzene
13. Trichloroethene
14. Bromodichloromethane
15. Toluene
16. Tetrachloroethene
17. Dibromochloromethane
18. Chlorobenzene
19. Ethylbenzene
20. *m*- + *p*-Xylene
21. *o*-Xylene
22. Tribromomethane
23. Bromobenzene

200160

#### Ordering information

Cat. No. for column length of

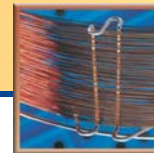
### PERMABOND® SE-54-HKW for volatile halogenated hydrocarbons

#### SE-54 optimised for volatile halogenated hydrocarbons

max. temperature for isothermal operation 300 °C, max. temperature for short isotherms in a temperature programme 320 °C

0.32 mm ID (0.5 mm OD)	1.80 µm film	25 m	<b>723945.25</b>	50 m	<b>723945.50</b>
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## GC capillary columns for special applications · triglyceride analyses

### OPTIMA® capillary columns for triglyceride analyses

The analysis of triglycerides is on the threshold to high temperature gas chromatography and requires short capillary columns (max. 25 m and 0.32 mm ID) with low-bleeding stationary phases.

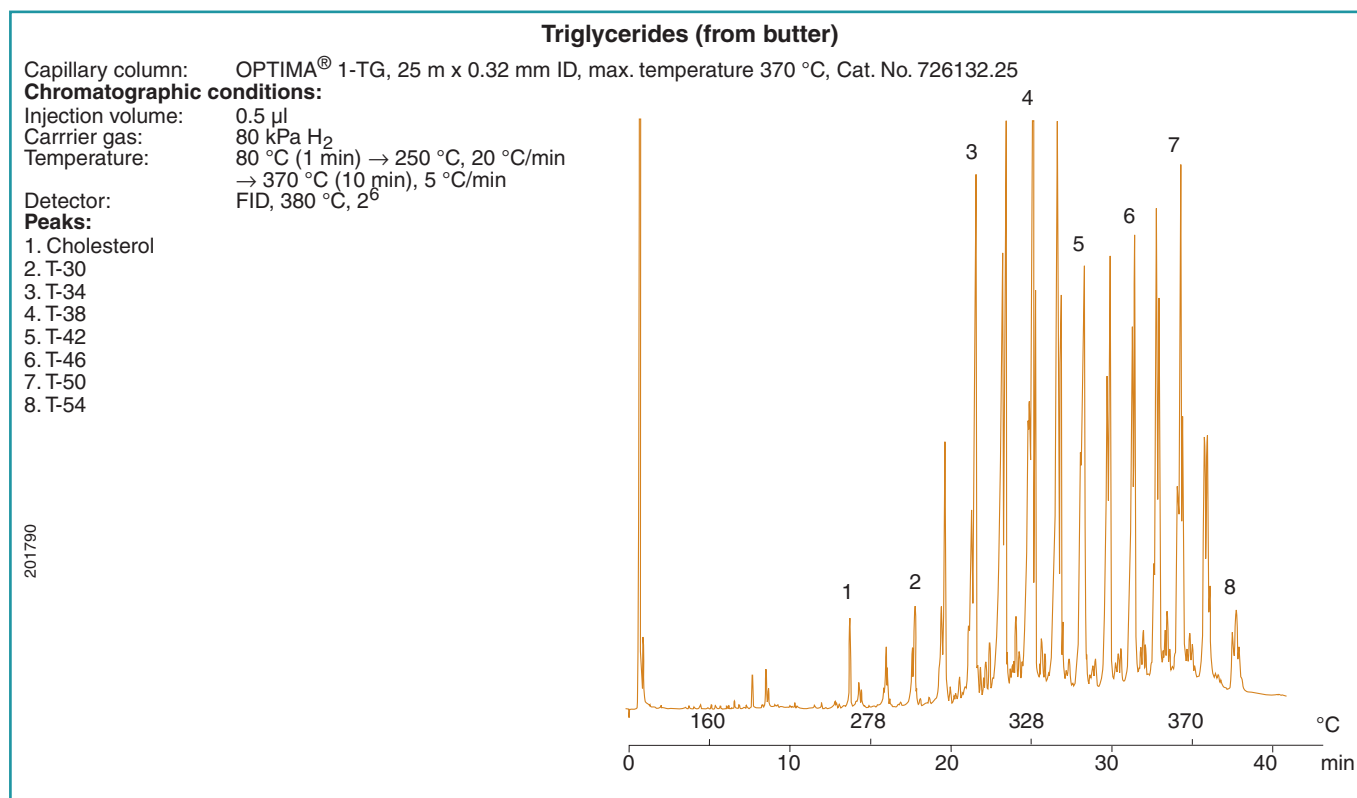
Our OPTIMA® programme – featuring low-bleeding, thermally stable stationary phases with optimum deactivation – offers two types of columns for this purpose:

- OPTIMA® 1-TG  
(similar phases: SPB-1 TG, DB-1 HT, 400-1 HT, HT-5)
- OPTIMA® 17-TG

The OPTIMA® 1-TG, 25 m x 0.32 mm ID (Cat. No. 726132.25) is the best choice in terms of low bleed level and offers separation according to carbon number.

If you need a separation according to degree of unsaturation, you should choose the OPTIMA 17-TG (Cat. No. 726131.25, 25 m and 0.32 mm ID for optimum separation efficiency).

The chromatogram shows a typical separation of triglycerides on OPTIMA® 1-TG.



Ordering information	Cat. No. for column length of	
	10 m	25 m
<b>OPTIMA® 1-TG</b>		
100% dimethylpolysiloxane, max. temperature 370 °C		
0.25 mm ID (0.4 mm OD)	726133.10	726133.25
0.32 mm ID (0.5 mm OD)	726132.10	726132.25
<b>OPTIMA® 17-TG</b>		
phenyl-methyl-polysiloxane (50% phenyl), max. temperature 370 °C		
0.32 mm ID (0.5 mm OD)	726131.10	726131.25



# Capillary columns for GC

## GC capillary columns for special applications

### Capillary column for silane analyses

Our capillary column PERMABOND® Silane has **not** been developed for the separation of trimethylsilyl derivatives, but especially for the analysis of monomeric silanes and chlorosilanes. It is also suited for the separation of dimeric siloxanes and silazanes, as shown in the following chromatogram.

#### Chloromethylsilanes

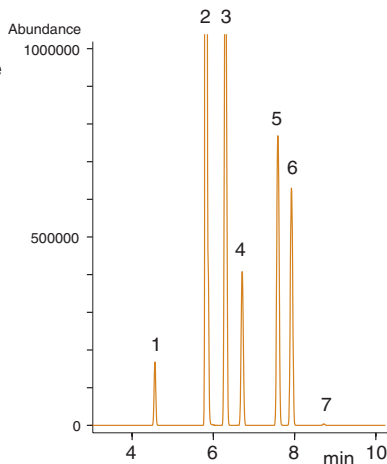
Capillary column: PERMABOND® Silane, 50 m x 0.32 mm ID, max. temp. 260/280 °C, Cat. No. 723409.50

#### Chromatographic conditions:

Injection volume: 0,5 µl gas  
 Carrier gas: 1 ml/min He (constant flow)  
 Split: 80 ml/min  
 Temperature: 50 °C → 100 °C, 5 °C/min  
 Detector: MSD 5971

#### Peaks:

1. Tetramethylsilane
2. Dichloromethane
3. Tetrachlorosilane
4. Chlorotrimethylsilane
5. Methyltrichlorosilane
6. Dichlorodimethylsilane
7. Hexamethyldisiloxane



### Capillary column for the determination of diethylene glycol

This capillary column is especially tested with diethylene glycol and recommended for the determination of diethylene glycol, e.g. for the quality control of wine.

#### Diethylene glycol standard in wine

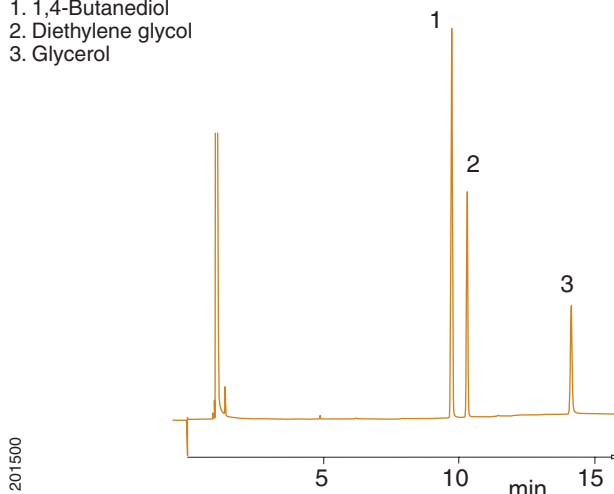
Capillary column: PERMABOND® CW 20 M-DEG, 25 m x 0.25 mm ID, max. temp. 220/240 °C, Cat. No. 723063.25

#### Chromatographic conditions:

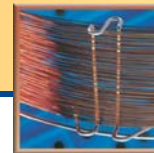
Injection volume: 0.5 µl  
 Carrier gas: 1.2 bar N<sub>2</sub>  
 Split: ~1 : 40  
 Temperature: 80 °C → 200 °C, 10 °C/min  
 Detector: FID 260 °C, 10 x 2<sup>2</sup>

#### Peaks:

- DEG standard
1. 1,4-Butanediol
  2. Diethylene glycol
  3. Glycerol



Ordering information	Cat. No. for column length of	
	25 m	50 m
<b>PERMABOND® Silane for silane analyses</b>		
For columns with 0.32 mm ID the max. temperature for isothermal operation is 260 °C, the max. temperature for short isotherms in a temperature programme is 280 °C; for 0.53 mm ID columns the max. temperatures are 240 and 260 °C, resp.		
0.32 mm ID (0.5 mm OD)	–	<b>723409.50</b>
0.53 mm ID (0.8 mm OD)	<b>723411.25</b>	–
<b>PERMABOND® CW 20 M-DEG, diethylene glycol tested</b>		
<b>Polyethylene glycol 20000</b> max. temperature for isothermal operation 220 °C, max. temperature for short isotherms in a temperature programme 240 °C		
0.25 mm ID (0.4 mm OD)		
0.25 µm film	<b>723063.25</b>	–
0.32 mm ID (0.5 mm OD)		
0.25 µm film	<b>723327.25</b>	–



## GC capillary columns for special applications · enantiomer analyses

### Capillary columns for enantiomer separation

Enantiodifferentiation is an important aspect in the activity of biological systems: enantiomers of chiral odour and flavour components as well as pharmaceuticals can possess very different properties. For this reason, separation and analysis of enantiomers gains increasing importance.

Among the methods available for this purpose, today chromatography provides the most impressive success.

Especially capillary gas chromatography with chiral stationary phases is the method of choice, because it features high resolution and sensitivity combined with simple detection and high precision. Reproducibility is excellent, the amount of substance required for the analysis is low.

The most important chiral phases can be assigned to two types:

- modified cyclodextrins (LIPODEX<sup>®</sup>, HYDRODEX)
- chiral polysiloxanes of the diamide type (e.g. L-CHIRASIL-VAL)

### Enantiomer separation based on chemically modified cyclodextrins

Cyclodextrins are cyclic oligosaccharides consisting of six ( $\alpha$ -cyclodextrin), seven ( $\beta$ -cyclodextrin) or eight ( $\gamma$ -cyclodextrin) glucose units bonded through  $\alpha$ -1,4-linkages.

By complete alkylation or by partial alkylation and (regioselective) acylation of these cyclodextrins one can synthesise a number of different derivatives with varying enantioselectivity, which have been intensively studied and which are well suited as chiral stationary phases for gas chromatographic enantiomer analyses.

These stationary phases have considerably broadened the applicability of gas chromatographic enantiomer separations: they allow the resolution of alcohols, diols, aldols, acetals, aminoalcohols, alkyl halides, amines, barbiturates, carbohydrates, cyanhydrins, ketones, carboxylic acids, amino acids, hydroxycarboxylic acids, lactones, esters, olefins and even alkanes.

**One important advantage of these phases is that many compounds can be analysed without derivatisation.** However, for certain substances enantioselectivity can be favourably influenced by formation of different derivatives.

Cyclodextrin phases also show some disadvantages:

- The basic separation mechanism, which is responsible for the large number of successful separations, does not allow a prediction, which phase could solve a given separation problem.
- Even for compounds with small structural differences or within a homologous series the enantiodifferentiation can be quite different.

For coating fused silica capillaries, cyclodextrins are either used as pure, undiluted phases (**FS-LIPODEX<sup>®</sup>**) or dissolved in polysiloxane (**FS-HYDRODEX**).

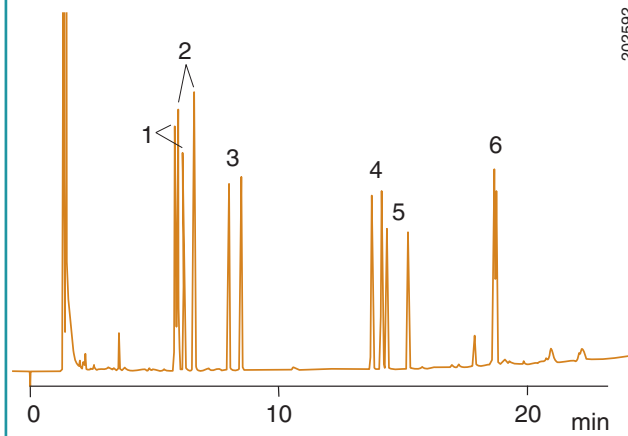
#### Enantiomer separation of amino acid methyl esters (TFA)

Capillary column: FS-LIPODEX<sup>®</sup> E, 25 m x 0.25 mm ID, max. temp. 200/220 °C, Cat. No. 723368.25

##### Chromatographic conditions:

Volume: 1  $\mu$ l  
 Carrier gas: 60 kPa H<sub>2</sub>  
 Split: about 1 : 100  
 Temperature: 90  $\rightarrow$  190 °C, 4 °C/min  
 Detector: FID, 250 °C, AT 2

**Peaks** (D is eluted before L except for proline: L before D)  
 1. Alanine, 2. Valine, 3. Leucine, 4. Proline, 5. Aspartic acid, 6. Phenylalanine



### Test mixtures for chiral GC capillary columns

Test mixture for	test compound (enantiomer mixture)	pack of	Cat. No.
LIPODEX <sup>®</sup> A, HYDRODEX $\beta$ -PM, $\beta$ -3P, $\beta$ -6TBDM, $\beta$ -TBDAc	Phenylethanol	1 ml	722321
LIPODEX <sup>®</sup> B	Methylbutyrolactone	1 ml	722322
LIPODEX <sup>®</sup> C, D	Phenylethylamine (TFA)	1 ml	722323
LIPODEX <sup>®</sup> E, G	Phenylethanol (TFA)	1 ml	722319
PERMABOND <sup>®</sup> L-CHIRASIL-VAL	Amino acids (TFA)-(lprop)	1 ml	722324

For applications with chiral MN columns please ask for our catalogue "Solutions for chiral chromatography"



# Capillary columns for GC

## GC capillary columns for special applications · enantiomer analyses

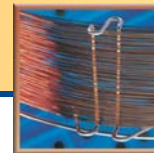
Summary of phases and ordering information	Cat. No. for column length of	
	25 m	50 m
(all 0.25 mm ID / 0.4 mm OD)		
<b>LIPODEX® fused silica capillary columns with cyclodextrin phases</b>		
<b>Capillary columns FS-LIPODEX® A**</b>		
hexakis-(2,3,6-tri-O-pentyl)- $\alpha$ -cyclodextrin, max. temperature* 200 / 220 °C recommended for carbohydrates, polyols, diols, hydroxycarboxylic acid esters, (epoxy-) alcohols, glycerol derivatives, spiroacetals, ketones, alkyl halides	723360.25	723360.50
<b>Capillary columns FS-LIPODEX® B**</b>		
hexakis-(2,6-di-O-pentyl-3-O-acetyl)- $\alpha$ -cyclodextrin, max. temperature* 200 / 220 °C recommended for lactones, diols (cyclic carbonates), aminols, aldols (O-TFA), glycerol derivatives (cyclic carbonates)	723362.25	723362.50
<b>Capillary columns FS-LIPODEX® C**</b>		
heptakis-(2,3,6-tri-O-pentyl)- $\beta$ -cyclodextrin, max. temperature* 200 / 220 °C recommended for alcohols, cyanhydrins, olefins, hydroxycarboxylic acid esters, alkyl halides	723364.25	723364.50
<b>Capillary columns FS-LIPODEX® D**</b>		
heptakis-(2,6-di-O-pentyl-3-O-acetyl)- $\beta$ -cyclodextrin, max. temperature* 200 °C / 220 °C recommended for amines (TFA), aminols (TFA), trans-cycloalkane-1,2-diols, trans-cycloalkane-1,3-diols (TFA), $\beta$ -amino acid esters	723366.25	723366.50
<b>Capillary columns FS-LIPODEX® E**</b>		
octakis-(2,6-di-O-pentyl-3-O-butyryl)- $\gamma$ -cyclodextrin, max. temperature* 200 °C / 220 °C recommended for $\alpha$ -amino acids, $\alpha$ - and $\beta$ -hydroxycarboxylic acid esters, alcohols (TFA), di- ols (TFA), ketones, pheromones (cyclic acetals), amines, alkyl halides, lactones	723368.25	723368.50
<b>Capillary columns FS-LIPODEX® G**</b>		
octakis-(2,3-di-O-pentyl-6-O-methyl)- $\gamma$ -cyclodextrin, max. temperature* 220 / 240 °C recommended for menthol isomers, ketones, alcohols, carboxylic acid esters, terpenes	723379.25	723379.50
<b>HYDRODEX fused silica capillary columns (diluted cyclodextrin phases)</b>		
<b>Capillary columns FS-HYDRODEX <math>\beta</math>-PM</b>		
heptakis-(2,3,6-tri-O-methyl)- $\beta$ -cyclodextrin diluted with OV-1701, max. temperature* 230 / 250 °C recommended for hydroxycarboxylic acid esters, alcohols, diols, olefins, lactones, acetals	723370.25	723370.50
<b>Capillary columns FS-HYDRODEX <math>\beta</math>-3P</b>		
heptakis-(2,6-di-O-methyl-3-O-pentyl)- $\beta$ -cyclodextrin diluted with OV-1701, max. temperature* 230 / 250 °C recommended for terpenes, dienes, allenes, terpene alcohols, 1,2-epoxyalkanes, carboxylic acids (esters), hydroxycarboxylic acid esters, pharmaceuticals, pesticides	723358.25	723358.50
<b>Capillary columns FS-HYDRODEX <math>\beta</math>-6TBDM</b>		
heptakis-(2,3-di-O-methyl-6-O- <i>t</i> -butyldimethyl-silyl)- $\beta$ -cyclodextrin diluted with OV-1701, max. temperature* 230 / 250 °C recommended for $\gamma$ -lactones, cyclopentanones, terpenes, esters, tartrates	723381.25	723381.50
<b>Capillary columns FS-HYDRODEX <math>\beta</math>-TBDAC</b>		
heptakis-(2,3-di-O-acetyl-6-O- <i>t</i> -butyldimethyl-silyl)- $\beta$ -cyclodextrin diluted with PS 086, max. temperature* 220 / 240 °C recommended for alcohols, esters, ketones, aldehydes, $\delta$ -lactones etc.	723384.25	723384.50

\* The first temperature is valid for isothermal operation, the second for short isotherms in a temperature programme.

\*\* LIPODEX® is patented under EP 0407 412 and US Re. 36.092

For fast GC columns with LIPODEX® E and HYDRODEX  $\beta$ -TBDM see page 341.

Other fast GC columns with cyclodextrin phases for enantiomer analysis are available on request.

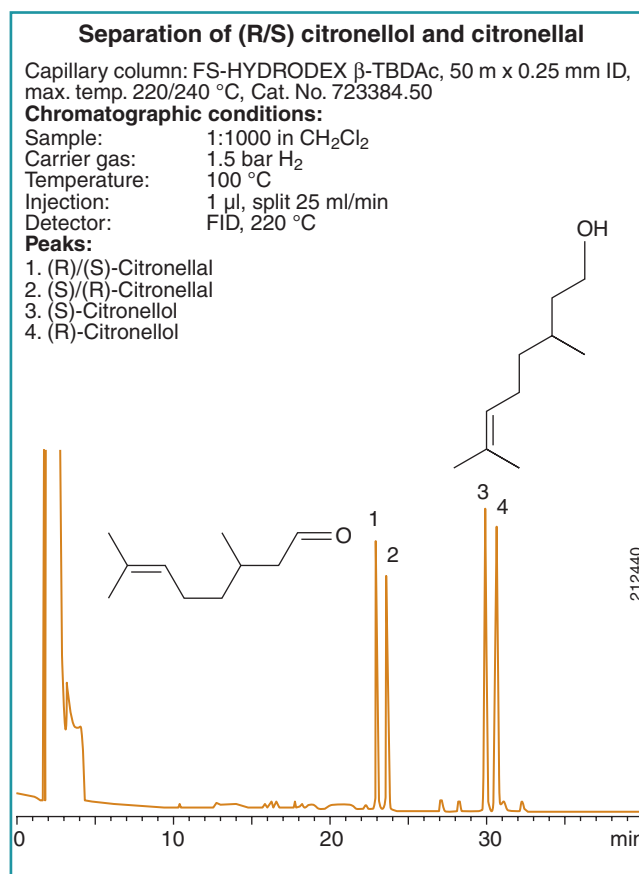
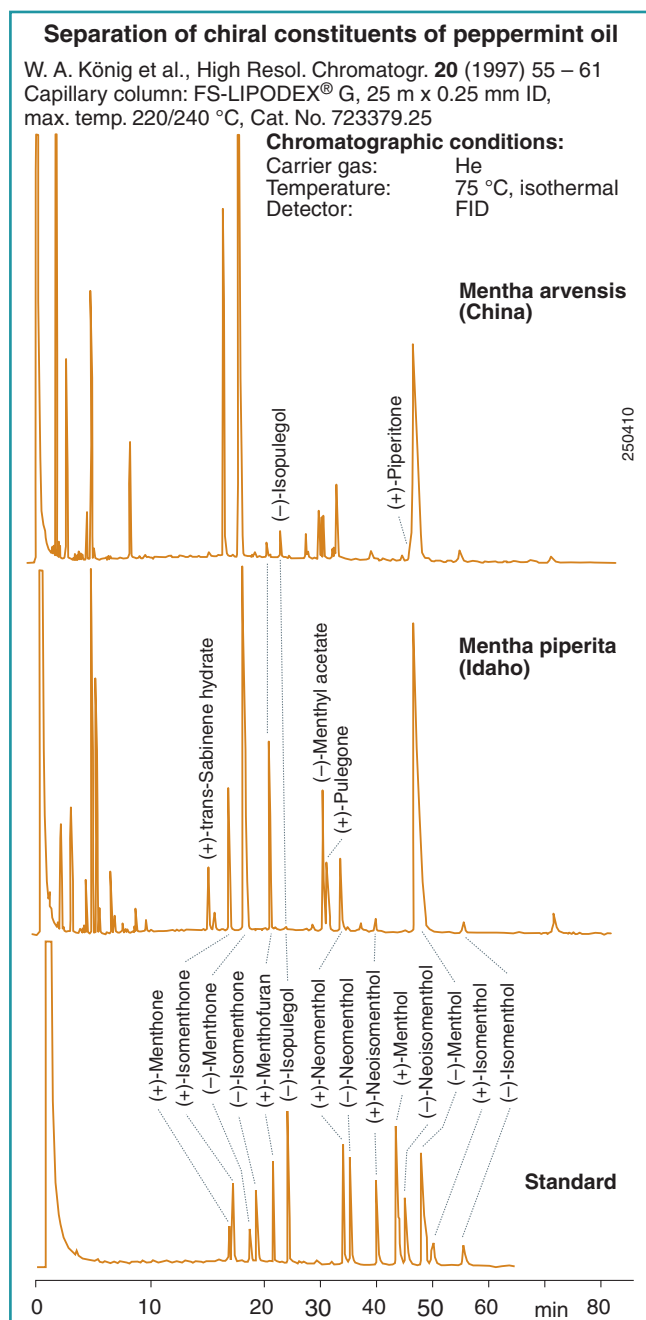


## GC capillary columns for special applications · enantiomer analyses

The lipophilic phases of the **LIPODEX**<sup>®</sup> series, which were introduced by W. A. König (Hamburg) are listed in the table above together with some typical applications to facilitate selection of a suitable column. LIPODEX<sup>®</sup> E and G are the LIPODEX<sup>®</sup> phases with the broadest range of applications. LIPODEX<sup>®</sup> E is also a valuable supplement to PERMA-BOND<sup>®</sup> L-CHIRASIL-VAL for amino acid analyses.

LIPODEX<sup>®</sup> G is especially well suited for the analysis of menthol isomers as is shown in the chromatogram below.

The high melting point of the methylated, hydrophilic cyclodextrin derivatives (**HYDRODEX**) is disadvantageous for use of the undiluted phases. V. Schurig (Tübingen) showed that methylated cyclodextrin phases can be operated at temperatures below their melting point, if they are diluted with polysiloxanes (e.g. OV-1701). Numerous examples for separations with heptakis-(2,3,6-tri-O-methyl)- $\beta$ -cyclodextrin in glass or fused silica capillary columns have been described in the literature.



### References:

- W. A. König, High Resol. Chromatogr. **16** (1993) 312 – 323
- W. A. König, High Resol. Chromatogr. **16** (1993) 569 – 586
- W. A. König, Gas Chromatographic Enantiomer Separation with Modified Cyclodextrins, Hüthig, Heidelberg, 1992
- W. A. König, The Practice of Enantiomer Separation by Capillary Gas Chromatography, Hüthig, Heidelberg, 1987
- V. Schurig, J. Chromatogr. A **906** (2001) 275 – 299

For applications with chiral MN columns please ask for our catalogue "Solutions for chiral chromatography"



# Capillary columns for GC

## GC capillary columns for special applications · enantiomer analyses

### Application of cyclodextrin phases

Stationary phases based on modified cyclodextrins are not available with chemical bonding of the phase to the fused silica surface. For this reason the phase can be partially dissolved when injecting large amounts of solvents with splitless or on-column injection techniques (e. g. with cold trap). The result could be formation of droplets at the column inlet with corresponding loss of efficiency.

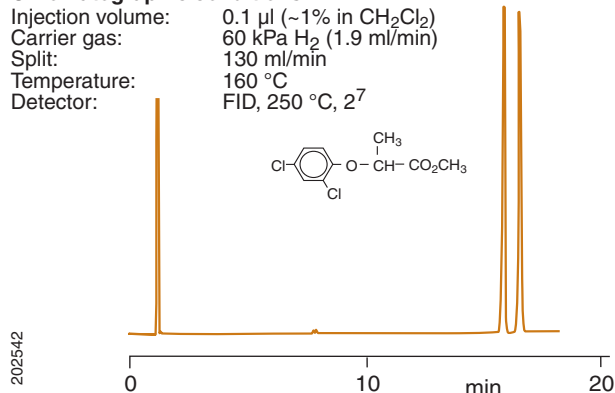
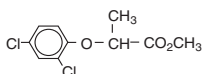
Since cyclodextrin phases have a lower capacity (compared to conventional or achiral stationary phases), you should avoid loss of efficiency due to overload conditions. To avoid the above-mentioned effects and maintain a good column life we recommend the use of low-boiling solvents like dichloromethane or pentane and a split technique (ratio  $\geq 1 : 50$ ).

### Enantiomer separation of dichlorprop methyl ester

Capillary column: HYDRODEX  $\beta$ -3P, 25 m x 0.25 mm ID, max. temperature 250 °C, Cat. No. 723358.25

#### Chromatographic conditions:

Injection volume: 0.1  $\mu$ l (~1% in  $\text{CH}_2\text{Cl}_2$ )  
Carrier gas: 60 kPa  $\text{H}_2$  (1.9 ml/min)  
Split: 130 ml/min  
Temperature: 160 °C  
Detector: FID, 250 °C,  $2^7$



### Separation of isomeric antiinflammatory drugs

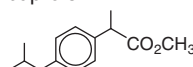
Capillary column: HYDRODEX  $\beta$ -6TBDM, 25 m x 0.25 mm ID, max. temperature 250 °C, Cat. No. 723381.25

#### Chromatographic conditions:

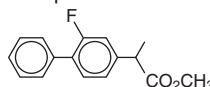
Carrier gas: He  
Temperature: 135 °C  $\rightarrow$  200 °C, 1 °C/min  
Detector: FID

#### Peaks:

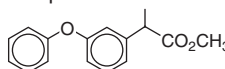
1. Ibuprofen



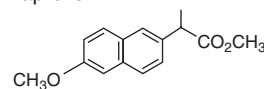
2. Flurbiprofen



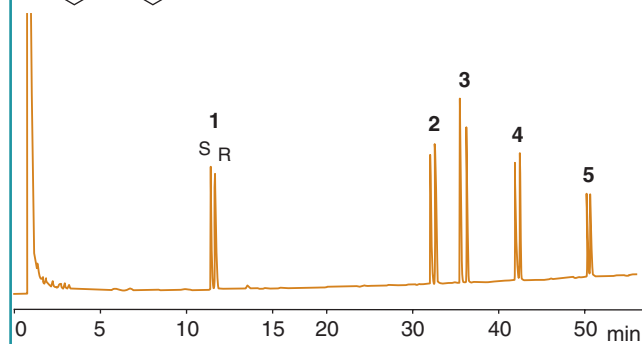
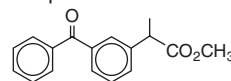
3. Fenopropfen



4. Naproxen



5. Ketoprofen



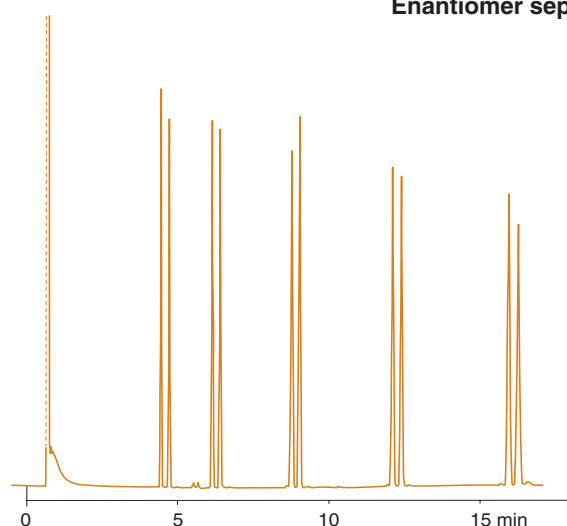
Courtesy of Prof. W.A. König, Hamburg, Germany

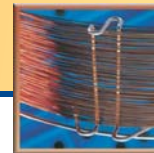
### Enantiomer separation of $\gamma$ -lactones C8 – C12

Capillary column: LIPODEX<sup>®</sup> E, 25 m x 0.25 mm ID, max. temperature 200/220 °C, Cat. No. 723368.25

#### Chromatographic conditions:

Injection volume: 1  $\mu$ l (~0.1% in methylene chloride)  
Carrier gas: 100 kPa  $\text{H}_2$  (2.7 ml/min)  
Split: 320 ml/min  
Temperature: 130 °C  $\rightarrow$  160 °C, 2 °C/min  
Detector: FID, 250 °C,  $2^6$





## GC capillary columns for special applications · enantiomer analyses

### PERMABOND® L-CHIRASIL-VAL

The diamide type chiral stationary phase L-CHIRASIL-VAL, which has been developed by E. Bayer and H. Frank for enantiomer separation of amino acids, is available from MACHEREY-NAGEL with chemical bonding (immobilisation) of the phase in fused silica capillaries:

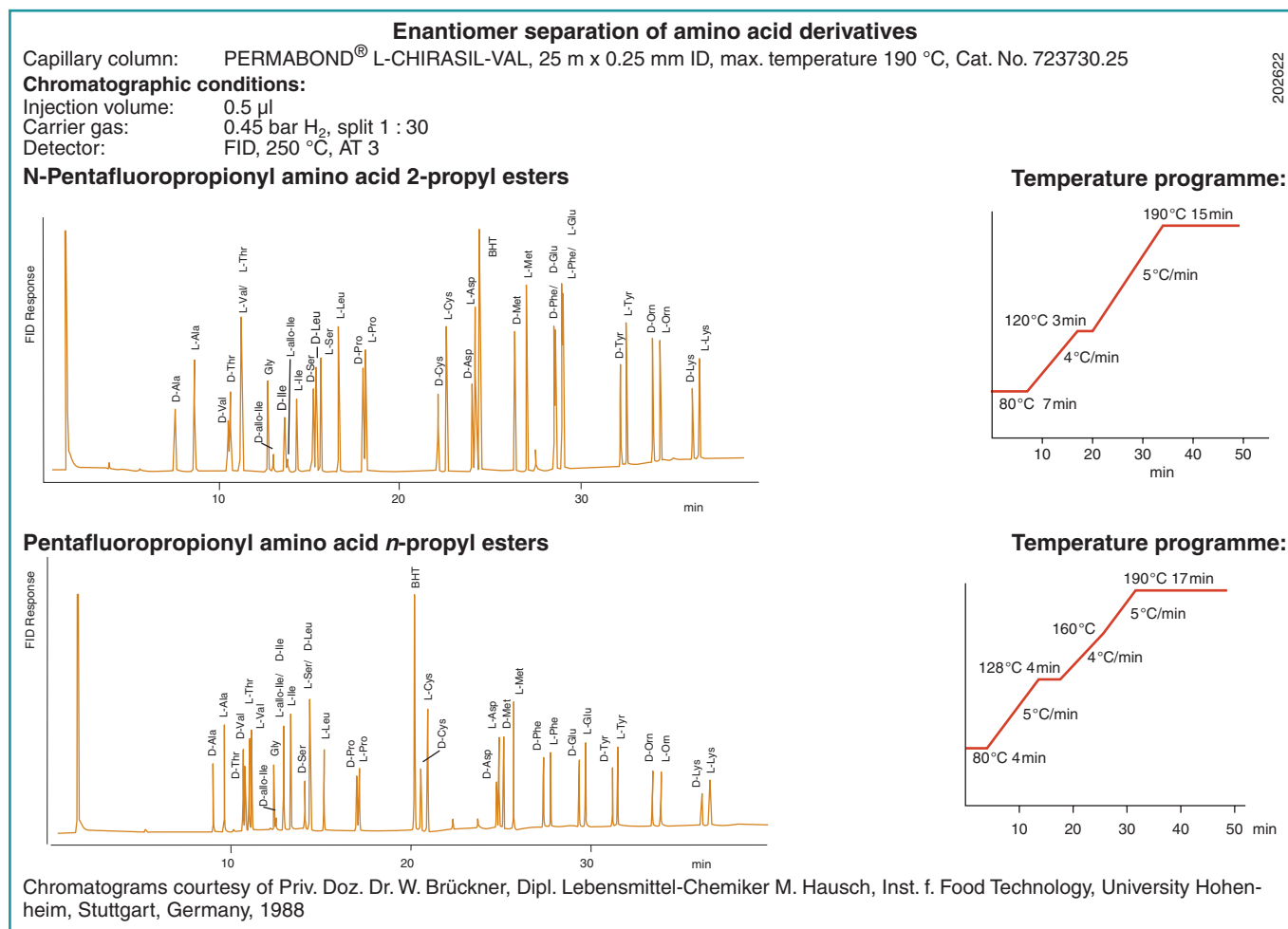
### PERMABOND® L-CHIRASIL-VAL

Thus the user can enjoy all the well-known advantages of immobilised phases such as:

- High stability and resulting longer column lifetime
- No dissolving of stationary phase when injecting large sample volumes

- The ability to remove contaminants from e.g. physiological samples by flushing, again increasing column life. When using L-CHIRASIL-VAL you should avoid the presence of strong acids or bases. Special care has to be taken to remove any excess of derivatising reagents because they can react with the phase causing destruction of the column.

**Derivatisation** does not only increase the volatility of the amino acids, but it also enhances resolution of the enantiomeric pairs as described by I. Abe et al. [HRC & CC 6 (1983) 366] and seen from the following chromatograms.



Ordering information	Cat. No. for column length of	
	25 m	50 m
<b>PERMABOND® L-CHIRASIL-VAL capillary columns for enantiomer separations</b>		
(N-2-methylpropionyl-L-valine-t-butylamide)-methylpolysiloxane, max. temperature 190 °C		
0.25 mm ID (0.4 mm OD)	723730.25	723730.50
0.32 mm ID (0.5 mm OD)	723732.25	723732.50

For applications with chiral MN columns please ask for our catalogue "Solutions for chiral chromatography"



# Capillary columns for GC

## Precolumns: untreated capillaries, retention gaps and deactivated capillaries

### Untreated capillaries

- for capillary electrophoresis
- for preparation of capillary columns
- for capillary LC applications

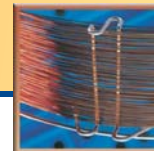
Ordering information	Cat. No. for capillary length of		
	1 m (pack of 3)	10 m (pack of 1)	25 m (pack of 1)
<b>Capillaries for electrophoresis</b>			
0.025 mm ID (0.375 mm OD)	723793.1	723793.2	
0.05 mm ID (0.375 mm OD)	723790.1	723790.2	
0.075 mm ID (0.2 mm OD)	723791.1	723791.2	
0.10 mm ID (0.375 mm OD)	723792.1	723792.2	
<b>Untreated capillaries</b>			
0.20 mm ID (0.4 mm OD)		723148.10	723148.25
0.25 mm ID (0.4 mm OD)		723101.10	723101.25
0.32 mm ID (0.5 mm OD)		723151.10	723151.25
0.53 mm ID (0.8 mm OD)		723501.10	723501.25
Untreated capillaries are supplied without cage. For empty cages please see page 369.			

### Deactivated capillary columns (precolumns)

Deactivated or untreated capillary columns can be used for the preparation of capillary columns. As precolumns, deactivated capillaries should be preferred to retention gaps, whenever a larger contamination capacity is required.

Ordering information	Cat. No. for capillary length of	
	10 m	25 m
<b>Methyl-Sil deactivated</b> (max. temperature 320 °C)		
0.25 mm ID (0.4 mm OD)	723106.10	723106.25
0.32 mm ID (0.5 mm OD)	723346.10	723346.25
0.53 mm ID (0.8 mm OD)	723558.10	723558.25
<b>Phenyl-Sil deactivated</b> (max. temperature 320 °C)		
0.25 mm ID (0.4 mm OD)	723108.10	723108.25
0.32 mm ID (0.5 mm OD)	723348.10	723348.25
0.53 mm ID (0.8 mm OD)	723560.10	723560.25
<b>CW deactivated</b> (max. temperature 250 °C)		
0.25 mm ID (0.4 mm OD)	723105.10	723105.25
0.32 mm ID (0.5 mm OD)	723349.10	723349.25
0.53 mm ID (0.8 mm OD)	723562.10	723562.25
Deactivated capillaries are supplied without cage. For empty cages please see page 369.		





## Precolumns: untreated capillaries, retention gaps and deactivated capillaries

### Retention gaps

The retention gap technique as developed by K. Grob (in combination with on-column injection) allows concentration of a large sample volume in the capillary column.

For this purpose a retention gap must be inert. In order to guarantee maximum migration velocity the retention gap must not exhibit any noticeable retention.

Choice of the retention gap depends on the solvent used: the flooded zone after injection should be between 20 – 30 cm/ $\mu$ l.

A Me-Sil retention gap is more inert than a Phe-Sil, while the Phe-Sil retention gap is less susceptible to contaminations. CW retention gaps can only be used up to 250 °C, while Me-Sil and Phe-Sil retention gaps are stable up to 320 °C.

Retention gaps can also be used as transfer lines or precolumns (contamination capacity about 5–10  $\mu$ g).

### Recommended application of retention gaps

Me-Sil retention gap:	only for use with n-hexane and diethyl ether
Phe-Sil retention gap:	for all solvents except methanol and water
CW retention gap:	for all solvents and especially for methanol and water

### Calculation example:

length of flooded zone:	about 20 – 30 cm/ $\mu$ l
retention gap:	10 m x 0.32 mm ID
capillary column:	25 m x 0.32 mm ID
max. injection volume:	about 30 – 50 $\mu$ l

Ordering information	Cat. No. for capillary length of	
	10 m	25 m
<b>Me-Sil retention gaps</b> (max temperature 320 °C)		
0.25 mm ID (0.4 mm OD)	723706.10	723706.25
0.32 mm ID (0.5 mm OD)	723707.10	723707.25
0.53 mm ID (0.8 mm OD)	723708.10	723708.25
<b>Phe-Sil retention gaps</b> (max temperature 320 °C)		
0.25 mm ID (0.4 mm OD)	723709.10	723709.25
0.32 mm ID (0.5 mm OD)	723710.10	723710.25
0.53 mm ID (0.8 mm OD)	723711.10	723711.25
<b>CW retention gaps</b> (max. temperature 250 °C)		
0.25 mm ID (0.4 mm OD)	723712.10	723712.25
0.32 mm ID (0.5 mm OD)	723713.10	723713.25
0.53 mm ID (0.8 mm OD)	723714.10	723714.25
Retention gaps are supplied without cage. For empty cages please see page 369.		



# Capillary columns for GC

## Precolumns: untreated capillaries, retention gaps and deactivated capillaries

Ordering information	Cat. No. for column length of	
	25 m	50 m
<b>Capillary columns FS-OV-1</b>		
100% dimethylpolysiloxane (max. temperature 300 °C)		
0.32 mm ID (0.5 mm OD)		
0.25 µm film	733302.25	733302.50
1.00 µm film	733323.25	733323.50
<b>Capillary columns FS-SE-30</b>		
100% dimethylpolysiloxane (max. temperature 300 °C)		
0.32 mm ID (0.5 mm OD)		
0.25 µm film	733306.25	733306.50
<b>Capillary columns FS-SE-54</b>		
5% diphenyl – 1% vinylmethyl – 94% dimethylpolysiloxane (max. temperature 300 °C)		
0.25 mm ID (0.4 mm OD)		
0.25 µm film	733056.25	733056.50
0.32 mm ID (0.5 mm OD)		
1.00 µm film	733325.25	733325.50
<b>Capillary columns FS-FFAP</b>		
<b>Polyethylene glycol 2-nitroterephthalic acid ester</b>		
max. temperature for isothermal operation 200 °C, max. temperature for short isotherms in a temperature programme 220 °C		
0.25 mm ID (0.4 mm OD)		
0.25 µm film	733116.25	733116.50
As a courtesy to our customers who do not want to change their methods with non-bonded capillaries, we still offer this small programme of fused silica capillaries with non-immobilised phases. Customised lengths (15, 30 or 60 m), film thicknesses or diameters are available on special request. Excellent replacements for these not chemically bonded stationary phases are the corresponding phases of our OPTIMA® or PERMABOND® series.		