Hayes Separations, Inc.

Analytical Polymers

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POROUS POLYMERS

Since the development of porous polymers for use in gas chromatography by Hollis and Hayes in the mid 1960's, very little has been done to improve their performance. Commercial polymers such as Porapak® and Chromasorb® have been available since this time for chromatographic use. However these commercially available polymers have been plagued with problems such as batch-to-batch variations, incomplete or inadequate cleanup and shrinkage. These variations and inconsistencies in production and handling have led to poor performance and reproducibility.

HayeSep® analytical polymers and packed columns are now available to chromatographers at a reasonable cost. Hayes Separations, Inc. takes pride in providing the necessary technical assistance to support our users. We guarantee that our polymers are better than any other on the market and we are continuing to develop and test new packings for specific separation problems.

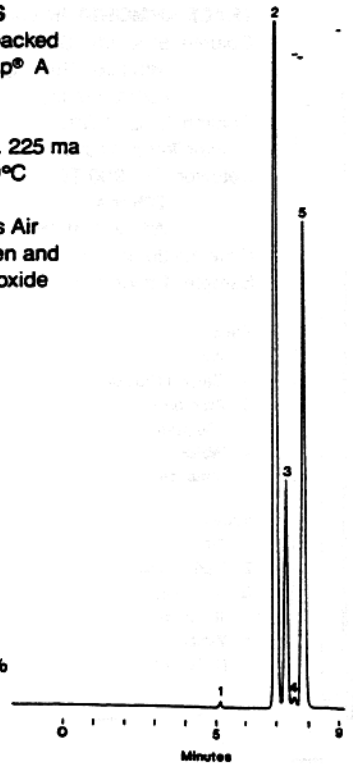
HayeSep® polymers are thoroughly cleaned and preconditioned for twelve hours under oxygen-free nitrogen before packaging. These handling techniques produce polymers which are consistently the same, with no shrinkage and minimum bleed. Columns packed with HayeSep® require minimum conditioning.

HayeSep® Polymer	Maximum Operating Temp.	Surface Area m²/gram	Tapped Bulk Density gram/cc	Polymer Composition*	Polarity (1=lowest 9=highest)
A	165°C	526	0.356	DVB (high purity) EGDM (high purity)	7
B	190°C	608	0.330	DVB/PEI	8
C	250°C	442	0.322	DVB/ACN	6
D	290°C	795	0.3311	DVB (high purity)	1
N	165°C	405	0.355	DVB/EGDM	9
P	250°C	165	0.420	DVB/Styrene	3
Q	275°C	582	0.351	DVB	2
R	250°C	344	0.324	DVB/NV2P	5
S	250°C	583	0.334	DVB/4VP	4
T	165°C	250	0.381	EGDM	10

*DVB Divinylbenzene
EGDM Ethyleneglycoldimethacrylate
PEI Polyethyleneimine
ACN Acrylonitrile
NV2P N-vinyl-2-pyrollidinone
4VP 4-vinyl-pyridine

HayeSep® A This polymer separates permanent gases (hydrogen, nitrogen, oxygen, argon, carbon monoxide, and nitric oxide) at ambient temperatures. It also exhibits good separation characteristics for the C2's, hydrogen sulphide and water at higher temperatures.

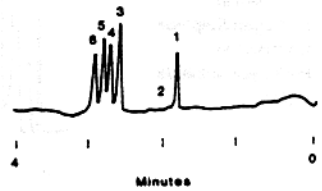
Figure 1
PERMANENT GASES
Column: 36′ × 1/8″ packed with HayeSep® A 80/100 mesh
Column Temp: 25°
Detector: P.E. 900 T.C. 225 ma Att. × 2 180°C
Flow: He 23 cc/min
Sample: 25 microliters Air plus Hydrogen and Carbon Monoxide



1. Hydrogen 5%
2. Nitrogen 48.5%
3. Oxygen 13%
4. Argon 0.5%
5. Carbon Monoxide 33%

Figure 2
PERMANENT GAS STANDARD 500 ppm
Column: 25′ × 1mm packed with HayeSep® A 170/200 mesh
Column Temp: 23°C
Flow: He 15 cc/min
Sample: 20 microliters

1. Neon
2. Hydrogen
3. Nitrogen
4. Oxygen
5. Argon
6. Carbon Monoxide



HayeSep® B Designed to separate the C1 and C2 amines as well as trace levels of ammonia and water, this polymer eliminates the need for caustic washing of material prior to packing.

Figure 3
AMINES #1
Column: 5′ × 1/8″ SS packed with HayeSep® B 80/100 mesh
Column Temp: 140° up to 190°C at 16°C/min
Injector Temp: 150°C
Detector: P.E. 900 T.C. 175 ma Att. × 8 180°C
Flow: He 30 cc/min
Sample: 0.2 microliters with on-column injection

1. Air
2. Water
3. Methylamine
4. Dimethylamine
5. Trimethylamine
6. Ethylene diamine

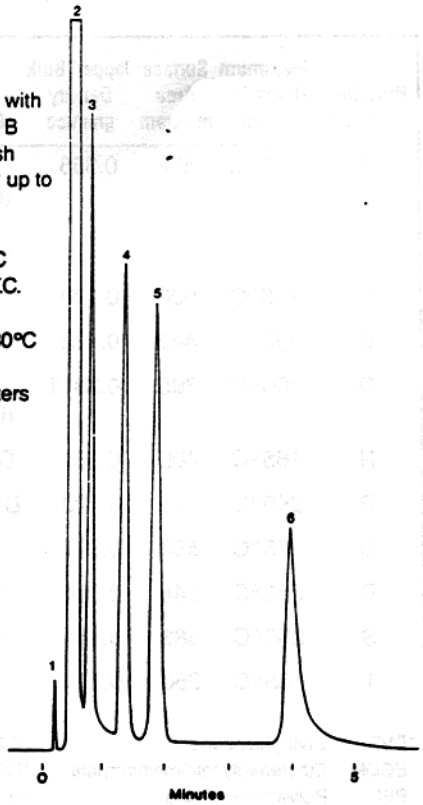
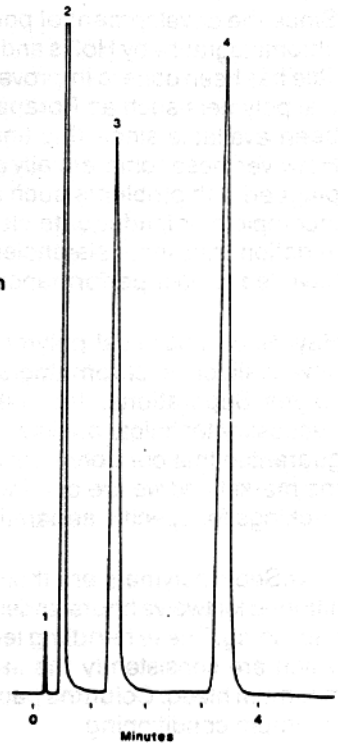


Figure 4
AMINES #2
Column: 5′ × 1/8″ packed with HayeSep® B 80/100 mesh
Column Temp: 140°C up to 190°C at 16°C/min
Injector Temp: 150°C
Detector: P.E. 900 T.C. 175 ma Att. × 8 180°C
Flow: He 30 cc/min
Sample: On-column injection

1. Air
2. Water
3. Ethylamine
4. Diethylamine



HayeSep® C This polymer is designed for polar hydrocarbons such as hydrogen cyanide, ammonia, hydrogen sulphide and water. HayeSep C® has similar separation characteristics to Chromosorb® 104.

Figure 5
AMMONIA IN HYDROGEN SULPHIDE
Column: 5′ × 1/8″ packed with HayeSep® C 80/100 mesh
Column Temp: 70°C
Injector Temp: 200°C
Detector: P.E. 900 T.C. 225 ma Att. × 2 180°C
Flow: He 30 cc/min
Sample: 100 microliters

1. Air
2. Carbon Dioxide
3. Ammonia
   Trace 1: approx 15%
   Trace 2: approx 1.5%
4. Hydrogen Sulphide
5. Unknown in Hydrogen Sulphide
6. Unknown in Hydrogen Sulphide
7. Water

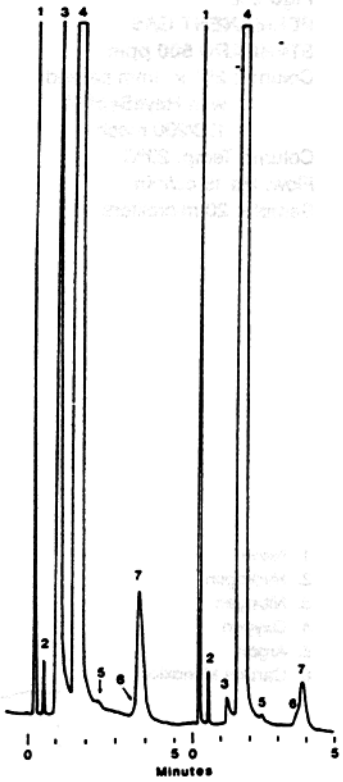
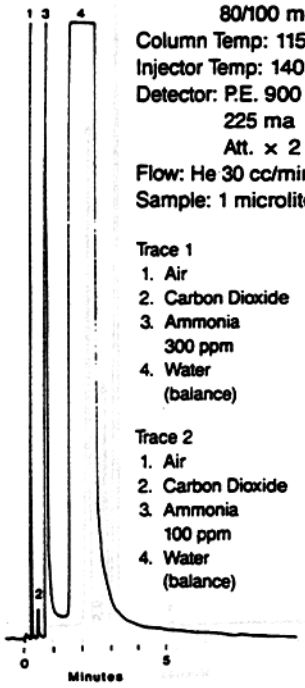
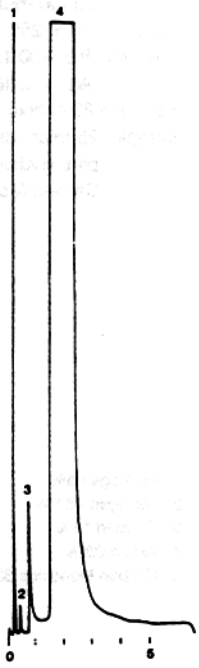


Figure 6
TRACE AMMONIA IN WATER
Column: 5′ × 1/8″ SS packed with HayeSep® C 80/100 mesh
Column Temp: 115°C
Injector Temp: 140°C
Detector: P.E. 900 T.C. 225 ma Att. × 2 180°C
Flow: He 30 cc/min
Sample: 1 microliter

Trace 1
1. Air
2. Carbon Dioxide
3. Ammonia 300 ppm
4. Water (balance)

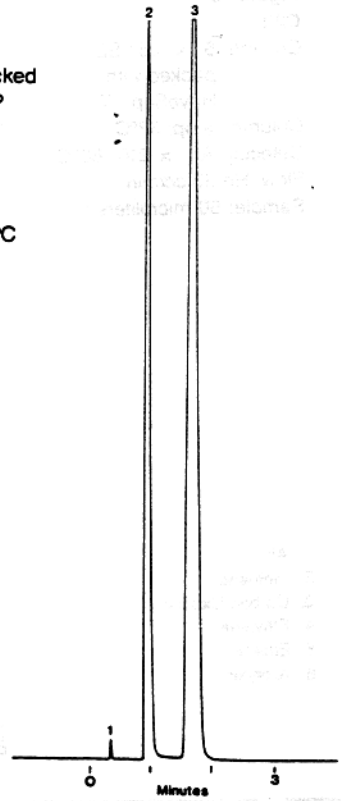
Trace 2
1. Air
2. Carbon Dioxide
3. Ammonia 100 ppm
4. Water (balance)





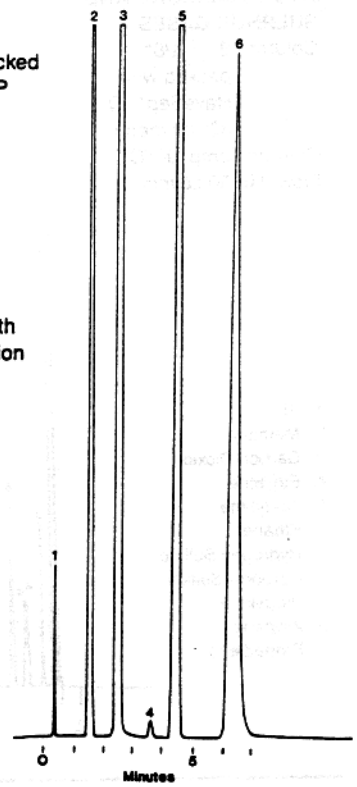
HayeSep® N, P, Q, R, S, and T These polymers are interchangeable with the Porapak® series for separations of low molecular weight materials containing halogens, sulphurs, water, alcohols, glycols, free fatty acids, esters, ketones and aldehydes.

Figure 7
AMMONIA
Column: 8′ × 1/8″ SS packed with HayeSep® P 60/80 mesh
Column Temp: 80°C
Injector Temp: 150°C
Manifold Temp: 180°C
Detector: T.C. 175 ma 200°C
Flow: He 30 cc/min
Sample: 0.1 microliters of NH_4OH with on-column injection



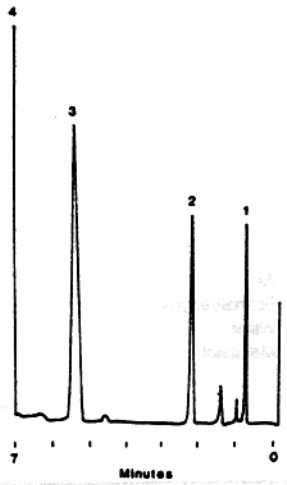
1. Air
2. Ammonia 35%
3. Water 65%

Figure 8
SOLVENTS
Column: 8′ × 1/8″ SS packed with HayeSep® P 60/80 mesh
Column Temp: 80°C up to 180°C at 16°C/min
Injector Temp: 150°
Manifold Temp: 180°C
Detector: 175 ma 200°C
Flow: He 30 cc/min
Sample: 0.2 microliters with on-column injection



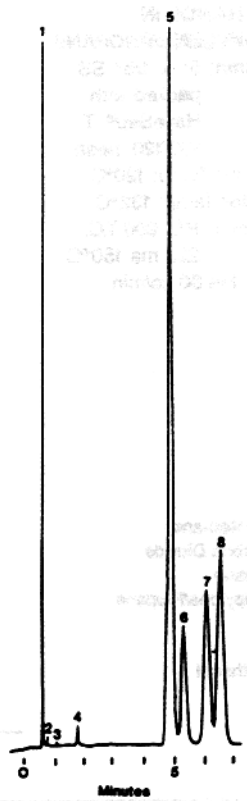
1. Air
2. Water
3. Methanol
4. Ethanol
5. Acetone
6. Chloroform

Figure 9
TRACE WATER ANALYSIS
Column: 9′ × 1/8″ Ni packed with HayeSep® R 80/100 mesh
Column Temp: 118°C
Flow: He 30 cc/min
Detector: Varian T.C. with Bendix On-Line Process Analyzer
Sample: 10 microliters Ethyl Chloride



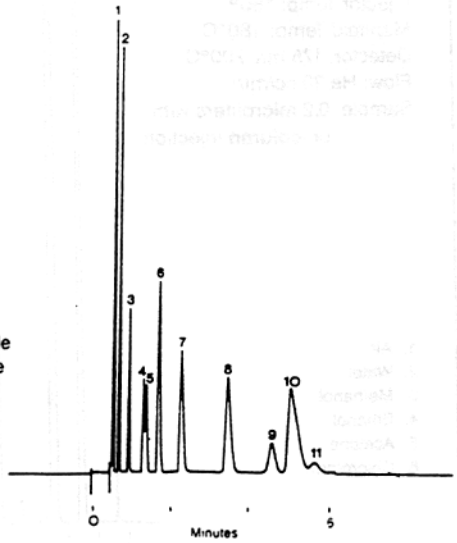
1. Air
2. Water 12 ppm
3. Hydrogen Chloride
4. Ethyl Chloride

Figure 10
MAPP GAS
Column: 10′ × 1/8″ SS packed with HayeSep® R
Column Temp: 80°
Flow: He 30 cc/min
Sample: 15 microliters



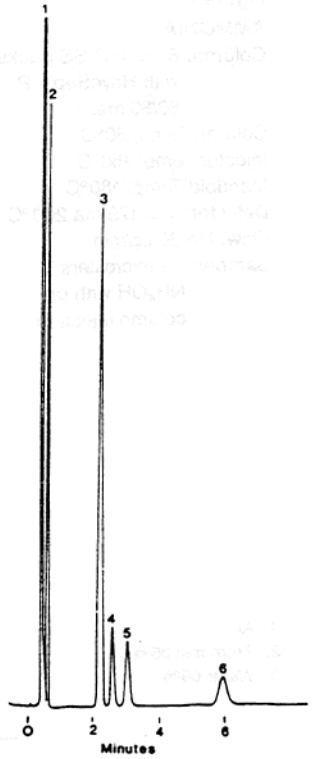
1. Air
2. Methane
3. Carbon Dioxide
4. Ethane
5. Propylene
6. Propane
7. Propadiene
8. Methyl Acetylene

Figure 11
HYDROCARBONS AND SULPHUR GASES
Column: 8′ × 1/8″
packed with
HayeSep® Q
80/100 mesh
Column Temp: 90°C
Flow: He 30 cc/min



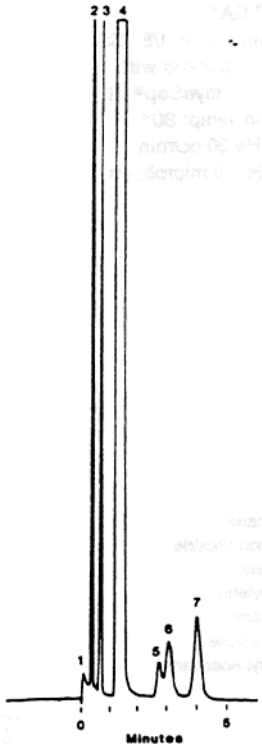
1. Air
2. Methane
3. Carbon Dioxide
4. Ethylene
5. Acetylene
6. Ethane
7. Hydrogen Sulfide
8. Carbonyl Sulfide
9. Propylene
10. Propane
11. Propadiene

Figure 12
C2's
Column: 5′ × 1/8″ SS
packed with
HayeSep® T
Column Temp: 32°C
Detector: Att. × 216 180°C
Flow: He 30 cc/min
Sample: 50 microliters



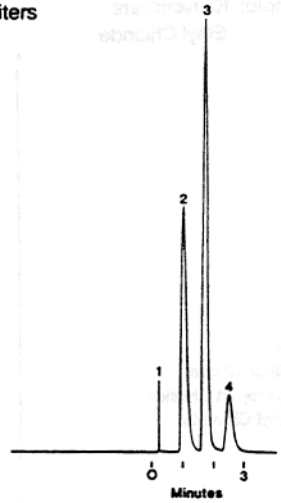
1. Air
2. Methane
3. Carbon Dioxide
4. Ethylene
5. Ethane
6. Acetylene

Figure 13
METHANOL IN PROPYLENE/PROPANE
Column: 5′ × 1/8″ SS
packed with
HayeSep® T
100/120 mesh
Column Temp: 120°C
Injector Temp: 132°C
Detector: P.E. 900 T.C.
225 ma 150°C
Flow: He 30 cc/min



1. Air/Methane
2. Carbon Dioxide
3. Ethane
4. Propylene/Propane
5. C4
6. C4
7. Methanol

Figure 14
FORMALDEHYDE
Column: 5′ × 1/8″ SS packed
with HayeSep® T
100/120 mesh
Column Temp: 132°C
Injector Temp: 165°
Detector: P.E. 900 T.C.
175 MA
Att. × 32 180°C
Flow: He 30 cc/min
Sample: 0.2 microliters



1. Air
2. Formaldehyde
3. Water
4. Methanol

INTRODUCING A UNIQUE NEW PRODUCT

HayeSep® D This new polymer made from high purity divinylbenzene is unavailable anywhere else. It has a high surface area and higher operating temperatures than competitive polymers. Available in four different porosities with surface areas from 790 to over 800 m^2/gram, this range allows flexibility, since in water/ethane separations porosity determines the order of elution.

These D formulations exhibit superior separation characteristics for light gases. Significant separation abilities include the separation of CO and CO_2 from room air at ambient temperatures and the separation of acetylene prior to other C2's. HayeSep® D is particularly useful in the separation and analysis of water and hydrogen sulphide.

Comparisons of D Formulations

	Average Diameter (microns)	Bulk Density gram/cc	Porosity %	Surface Area m^2/gram
Dip	.0317	.3283	69.1	774
D	.0308	.3311	70.35	803
D_B	.0332	.3334	64.2	781

Figure 15
SCOTT MIX 237
Column: 20′ × 1/8″ Ni packed with HayeSep® D 100/120 mesh
Column Temp: 25°C
Injector Temp: 100°C
Detector: P.E. 900 T.C. 225 ma 140°C
Flow: He 30 cc/min
Sample: Valco valve 50 microliters vapor (ambient)

1. Nitrogen (balance)
2. Oxygen 7% Att.×8
3. Carbon Monoxide 7% Att.×8
4. Methane 4.5% Att.×4
5. Carbon Dioxide 15% Att.×4

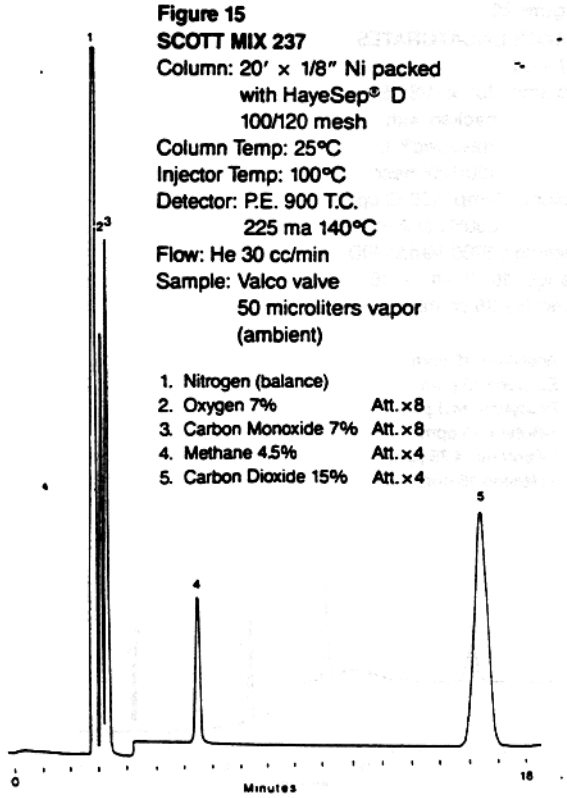


Figure 16
GAS MIXTURE
Column: 10′ × 1/8″ SS packed with HayeSep® D 100/120 mesh
Column Temp: 80°C
Injector Temp: 140°C
Detector: P.E. 900 T.C. 225 ma Att. × 4
Flow: He 30 cc/min
Sample: Valco valve 100 microliters

1. Nitrogen (balance)
2. Carbon Dioxide 2%
3. Nitrous Oxide 3%
4. Water 0.5%
5. Hydrogen Sulphide 3%

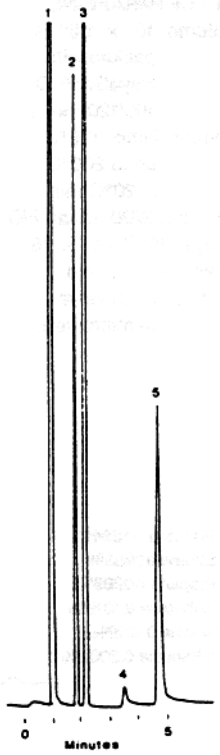
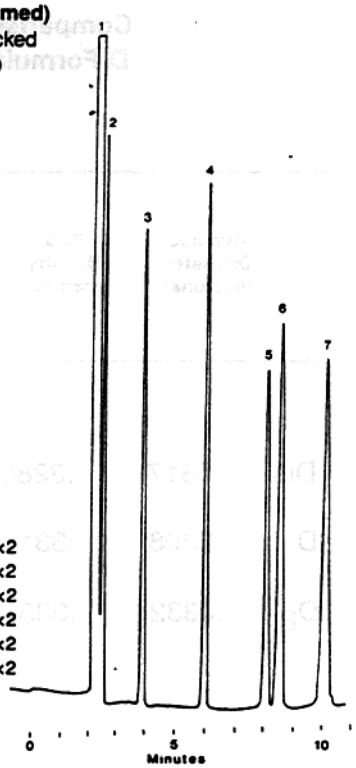
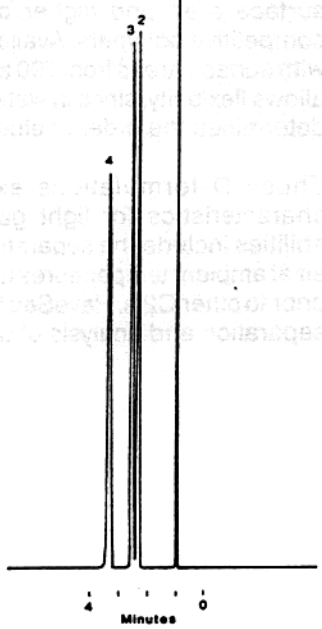


Figure 17
SCOTT MIX 216 (Programmed)
Column: 20′ × 1/8″ Ni packed with HayeSep® D 100/120 mesh
Column Temp: 40°C/2 min programmed up to 110°C at 24°C/min
Injector Temp: 100°C
Detector: P.E. 900 T.C. 225 ma 140°C
Flow: He 30 cc/min
Sample: Valco valve 100 microliters (ambient)



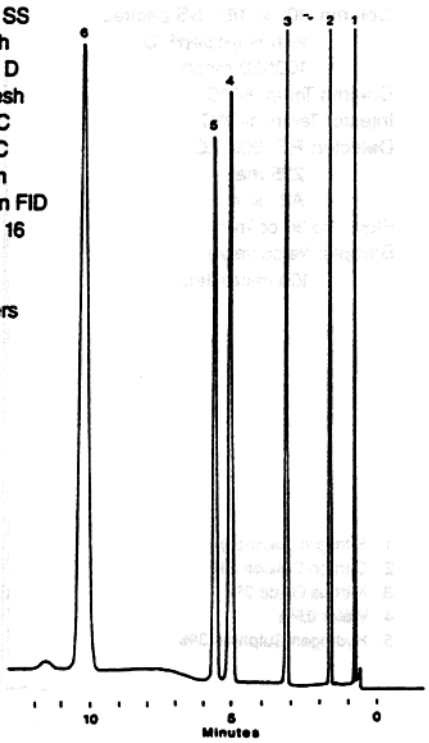
1. Nitrogen (balance)
2. Carbon Monoxide 1% Att.×2
3. Methane 1% Att.×2
4. Carbon Dioxide 1% Att.×2
5. Acetylene 1% Att.×2
6. Ethylene 1% Att.×2
7. Ethane 1% Att.×2

Figure 18
C1 - C2's
Column: 10′ × 1/8″ SS packed with HayeSep® D 100/120 mesh
Column Temp: 80°C Isothermal
Detector: 3700 Varian FID
Range: 10^{-11} Att. × 16
Flow: He 35 cc/min



1. Methane 1%
2. Acetylene 1%
3. Ethylene 1%
4. Ethane 1%

Figure 19
C1 - C5 PARAFFINS
Column: 10′ × 1/8″ SS packed with HayeSep® D 100/120 mesh
Column Temp: 120°C up to 200°C at 20°C/min
Detector: 3700 Varian FID
Range: 10^{-11} Att. × 16
Flow: He 35 cc/min
Sample: Valco valve 50 microliters



1. Methane 0.1894%
2. Ethane 0.0965%
3. Propane 0.0989%
4. Isobutane 0.1019%
5. Butane 0.1019%
6. n-Pentane 0.2002%

Figure 20
TRACE UNSATURATES
C2 - C6
Column: 10′ × 1/8″ SS packed with HayeSep® D 100/120 mesh
Column Temp: 120°C up to 200°C at 24°C/min
Detector: 3700 Varian FID
Range: 10^{-11} Att. × 16
Flow: He 35 cc/min

1. Acetylene 16 ppm
2. Ethylene 15 ppm
3. Propylene 14.3 ppm
4. 1-Butene 15 ppm
5. 1-Pentene 14.75 ppm
6. 1-Hexene 16 ppm

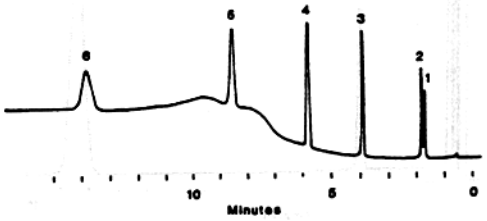
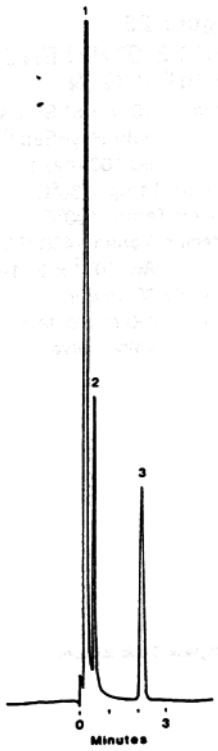
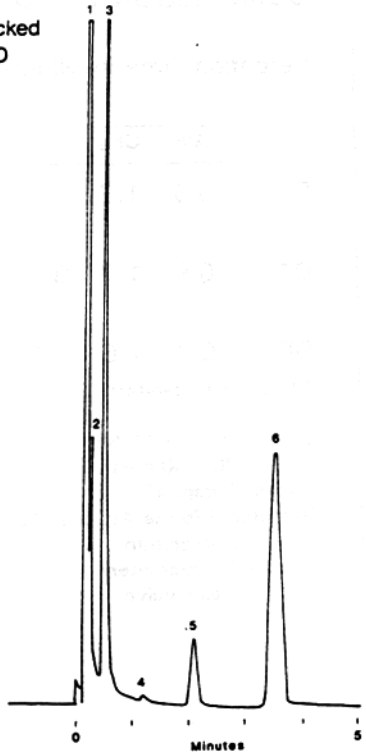


Figure 21
TRACE ACETALDEHYDE IN AIR 2500 ppm
Column: 3′ × 1/8″ SS packed with HayeSep® D 100/120 mesh
Column Temp: 100°C
Injector Temp: 140°C
Detector: P.E. 900 T.C. 225 ma 140°C
Flow: He 30 cc/min
Sample: Valco valve 100 microliters



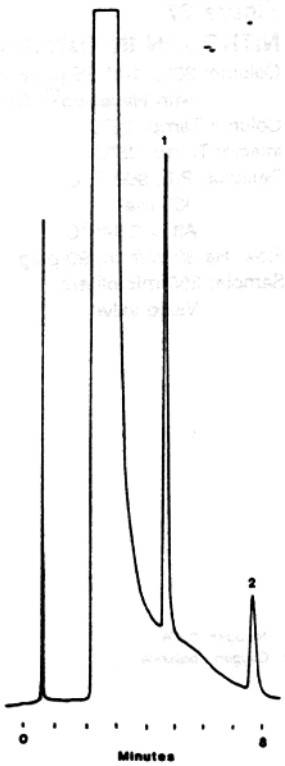
1. Air
2. Water
3. Acetaldehyde 2500 ppm (vol.)

Figure 22
TEQUILA HEADSPACE
Column: 3′ × 1/8″ SS packed with HayeSep® D 80/120 mesh
Column Temp: 100°
Injector Temp: 140°C
Detector: P.E. 900 T.C. 225 ma 140°C
Flow: He 30 cc/min
Sample: Valco valve 100 microliters



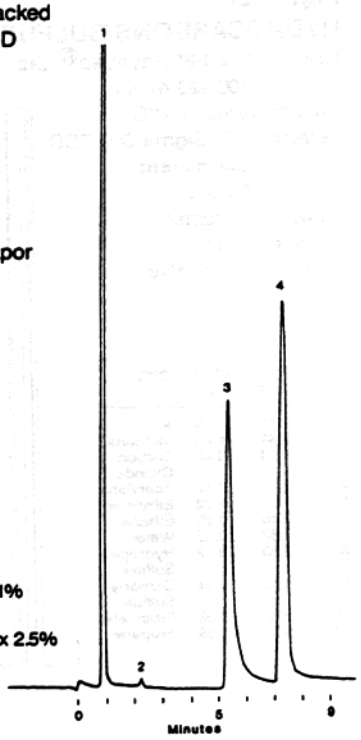
1. Air Att.×1
2. Carbon Dioxide Att.×1
3. Water Att.×1
4. Methanol Att.×1
5. Acetaldehyde Att.×1
6. Ethanol Att.×8

Figure 23
TRACE ALCOHOLS IN WATER
Column: 10′ × 1/8″ packed with HayeSep® D 80/100 mesh
Column Temp: 75°C up to 150°C at 16°C/min
Flow: He 33 cc/min
Injector Temp: 125°C
Detector: P.E. 900 T.C. 225 ma Att. × 1 140°C
Sample: 3 microliters



1. Methanol 500 ppm
2. Ethanol 200 ppm

Figure 24
HYDROGEN SULPHIDE
Column: 10′ × 1/8″ Ni packed with HayeSep® D 100/120 mesh
Column Temp: 60°C
Injector Temp: 100°C
Detector: P.E. 900 T.C. 225 ma 140°C
Flow: He 30 cc/min
Sample: Valco valve 50 microliters vapor (ambient)



1. Air (balance)
2. Carbon Dioxide approx 0.1%
3. Water approx 2.5%
4. Hydrogen Sulphide approx 2.5%

COMPARISON OF "D" FORMULATIONS

Retention Time in Minutes

	AIR	CH_4	CO_2	C_2H_2	C_2H_4	C_2H_6	H_2O
Dip	0.9	1.7	3.1	5.4	5.8	8.3	9.0
D*	0.9	1.7	3.1	5.8	6.1	8.4	8.6
DB	0.9	1.6	3.1	6.1	6.6	8.7	8.1

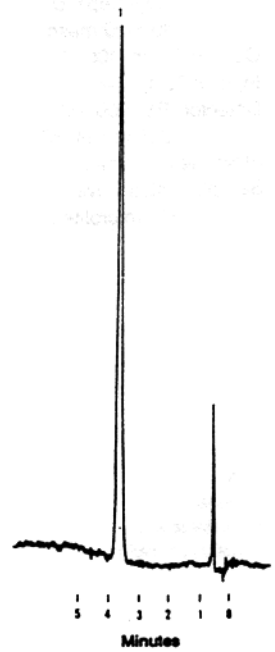
*This is our standard D.

Column: 10' x 1/8" SS
80/100 mesh
Column Temp: 45°C
Detector: 175 ma Att. x 2 150°
Flow: He 30 cc/min
Sample: 50 microliters
Valco valve

Figure 25
TRACE ETHYLENE OXIDE IN NITROGEN

Column: 10' x 1/8" SS packed
with HayeSep® D
80/100 mesh
Column Temp: 130°C
Injector Temp: 100°C
Detector: Varian 1400 F.I.D.
Att. 10^{-12} x 2 140°C
Flow: He 30 cc/min
Sample: 250 microliters
Valco valve

1. Ethylene Oxide 23 ppm

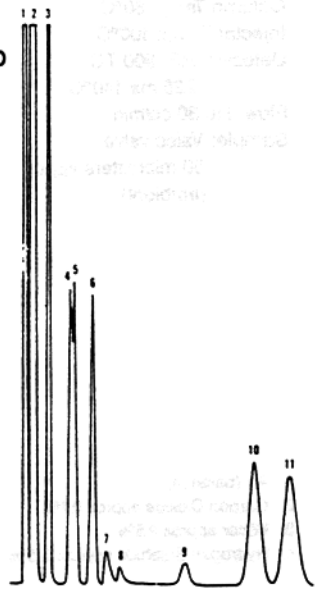


Courtesy of John Booker Co.

Figure 26
HYDROCARBONS/SULFUR GASES

Column: 9' x 1/8" HayeSep® Dip
100/120 mesh
Column Temp: 100°C
Detector: P.E. Sigma 300 TCD
Low current
Att. x 1
Flow: He 30 cc/min
Sample: 0.5 cc
Valco valve

PEAK	RET. TIME	AREA %	CPD
1.	0.71	31.59	Air
2.	0.86	46.88	Methane
3.*	1.23	5.48	Carbon Dioxide
4.	1.71	2.17	Acetylene
5.	1.79	2.72	Ethylene
6.	2.19	3.09	Ethane
7.	2.52	0.45	Water
8.	2.83	0.19	Hydrogen Sulfide
9.	4.30	0.44	Carbonyl Sulfide
10.	5.82	3.36	Propylene
11.	6.57	3.59	Propane



Courtesy of John Booker Co.

Figure 27
NITROGEN IN OXYGEN

Column: 30' x 1/8" SS packed
with HayeSep® DB
Column Temp: 25°C
Injector Temp: 25°C
Detector: P.E. 900 T. C.
300 ma
Att. x 2 140°C
Flow: He 30 cc/min, 90 psig
Sample: 250 microliters
Valco valve

1. Nitrogen 0.4%
2. Oxygen - balance