zNose® Performance Report

Detection of Common Volatile Organic Vapors using Helium and Nitrogen carrier gases in short and long db-624 columns

Description of Methods and Tests Performed

A portable chemical vapor analyzer (zNose™) was used to quantify the concentration of common volatile organic vapors. The zNose® is a GC/SAW containing a miniature tenax preconcentrator-injector, an ultra-fast gas chromatographic column, and a solid-state surface acoustic wave (SAW) detector.

This report describes an initial investigation focused on the exploring the use of nitrogen as a carrier gas rather than helium. Both handheld and benchtop instruments equipped with 1-meter and 5-meter capillary (db-624) columns were used to detect 15 common volatile organic vapors. Test vapor standards were created by injecting septa-sealed 250 mL bottles with measured amounts of hexane, heptane, octane, decane, benzene, toluene, ethyl benzene, 1,2-dichloroethylene, carbon tetrachloride, trichloroethylene, tetrachloroethene, and o-xylene in methanol.

Three different standard vapors, designated as n-alkanes, BTE, and Cal2, were prepared according to the worksheets shown in Figures 1-3. The top portion of each worksheet describes the preparation of a stock solution used for injections. In Figure 1 a stock solution of 2000 microliters of solvent (methanol) to which is added 5 microliters of hexane and 124 microliters of heptane, octane, nonane, and decane is described.

The lower portion of the worksheet calculates container vapor concentration after injection of a selected amount of stock solution. In Figure 1, injecting 5 microliters of stock solution into a 250 mL container produces alkane vapor concentrations in the low ppm range.

Analyte Parameters					Dilution
The volume (ul) of solvent used to make the stock solution:					Volume (ul) 2000
If the soultion is "neat" enter "neat" into solution concentration.					
Analyte	Molecular Weight	Solution Conc. mg/ul	Vol. of Analyte ul	Density g/mL	Concentration ng/ul
Hexane (C6)	86	neat	5	0.6548	1637.0
Septane (C7)	100	neat	1.25	0.69	431.3
Octane (C8)	114	neat	1.25	0.702	438.8
Nonane (C9)	128	neat	1.25	0.717	448.1
Decane (C10)	142	neat	1.25	0.73	456.3

Vapor Concentration and Mass Injected				Mass Injected from Direct Injection
Values required to calculate total mass injected	Samp. Flow	25	ml/min	
	Samp. Time	10	seconds	
Enter the ambient temperature (C):			22.5	
The volume (ml) of the sample container			250	
Enter the volume (ul) of stock injected:			5	Direct Injection Volume (ul)
Analyte concentration is:				0.2

Analyte	Vapor Conc. ng/mL		Press./760mm ppm	Mass Injected (ng)	Direct Injection Mass (ng)
Hexane (C6)	32.74		9.231	136.42	327.400
Septane (C7)	8.63		2.091	35.94	86.250
Octane (C8)	8.78		1.867	36.56	87.750
Nonane (C9)	8.96		1.698	37.34	89.625
Decane (C10)	9.13		1.558	38.02	91.250

Figure 1- Worksheet for producing c6-c10 alkane vapor standards.

Analyte Parameters					Dilution
The volume (ul) of solvent used to make the stock solution:					Volume (ul) 2000
If the soultion is "neat" enter "neat" into solution concentration.					
Analyte	Molecular Weight g/ml	Solution Conc. mg/ul	Vol. of Analyte ul	Density g/mL	Concentration ng/ul
Benzene	78.12	neat	5	0.88	2200.0
Toluene	92.15	neat	5	0.865	2162.5
Ethylbenzene	106.17	neat	5	0.867	2167.5

Vapor Concentration and Mass Injected				Mass Injected from Direct Injection
Values required to calculate total mass injected	Samp. Flow	25	ml/min	
	Samp. Time	10	seconds	
Enter the ambient temperature (C):		22.5		
The volume (ml) of the sample container		250		
Enter the volume (ul) of stock injected:		5		Direct Injection Volume (ul)
Analyte concentration is:				0.2

Analyte	Vapor Conc. ng/mL		Press./760mm ppm	Mass Injected (ng)	Direct Injection Mass (ng)
Benzene	44.00		13.658	183.33	440.000
Toluene	43.25		11.381	180.21	432.500
Ethylbenzene	43.35		9.901	180.63	433.500

Figure 2- Worksheet for producing BTE vapor standards.

Analyte Parameters					Dilution
The volume (ul) of solvent used to make the stock solution:					Volume (ul) 1000
If the soultion is "neat" enter "neat" into solution concentration.					
Analyte	Molecular Weight	Solution Conc. mg/ul	Vol. of Analyte ul	Density g/mL	Concentration ng/ul
cis 1,2[dichloroethylene	96.94	neat	10	1.284	11910.9
carbon tetrachloride	153.32	neat	60	1.519	84545.5
trichloroethylene	131.39	neat	4	1.464	5432.3
tetrachloroethene	165.83	neat	2	1.623	3011.1
o-xylene	106.17	neat	2	0.87	1614.1

Vapor Concentration and Mass Injected				Mass Injected from Direct Injection
Values required to calculate total mass injected	Samp. Flow	25	ml/min	
	Samp. Time	10	seconds	
Enter the ambient temperature (C):		22.5		
The volume (ml) of the sample container		250		
Enter the volume (ul) of stock injected:		5		Direct Injection Volume (ul)
Analyte concentration is:				0.2

Analyte	Vapor Conc. ng/mL		Press./760mm ppm	Mass Injected (ng)	Direct Injection Mass (ng)
cis 1,2[dichloroethylene	238.22		59.588	992.58	2382.189
carbon tetrachloride	1690.91		267.430	7045.45	16909.091
trichloroethylene	108.65		20.051	452.69	1086.456
tetrachloroethene	60.22		8.806	250.93	602.226
o-xylene	32.28		7.373	134.51	322.820

Figure 3- Worksheet for producing Cal2 vapor standards.

zNose® Quantification and Testing Procedures

The zNose™ is an ultra-fast gas chromatograph which can speciate and quantify volatile organic vapors in as fast as 10 seconds. The system is equipped with a vapor preconcentrator, a direct heated 1or 5 meter capillary column, and a solid-state non-specific detector with electronically variable sensitivity. The sensitivity of a measurement is controlled by the detector crystal temperature and vapor sampling time. Compound identification is based upon retention time. An expandable library of compounds and their odors using retention time indexing (Kovats indices) to n-alkanes vapor standards is part of system software.

Figure 4- The model 7100 zNose® is a portable benchtop GC with an internal tank for carrier gas. Approximately 300 measurements can be performed with a single tank of gas. Both disposable and re-chargeable tanks are available.

Three zNose® instruments with dB 624 columns were used for testing vapor standards. System A was a model 4200 (handheld) with a 1-meter column. Systems B and C were model 7100 (benchtop) with 1-meter and 5-meter column respectively. Linear temperature programming from 40°C to 160°C was used. Two GC-method files were created to allow testing with either ramping rates of 5°C/sec or 10°C/sec.

Three standard vapors (Alkanes, BTE, and Cal2) were prepared in septa-sealed 250-mL bottles. Replicate measurements were used to test each of the standard vapors. A series of vertically offset 10-second chromatograms illustrating the procedure used is shown in Figure 5. A 1-meter column and a 5°C/sec method produced half-height peak-widths of 200 milliseconds and a maximum of 50 compounds can be resolved in 10 seconds.

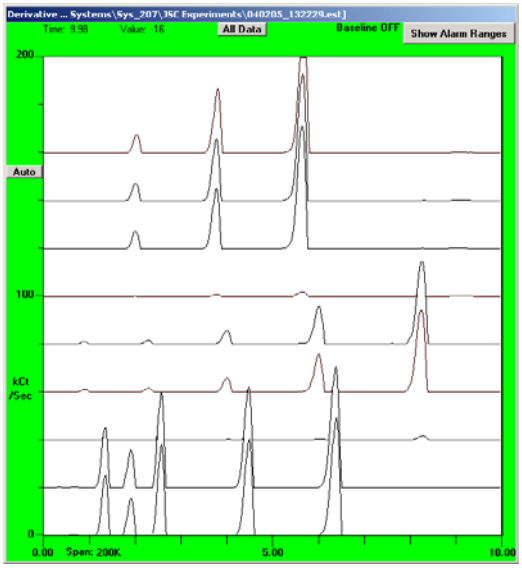


Figure 5-testing three bottles containing BTE, Alkanes, andCal2 vapors.

Once an analyte (peak) was identified single-point response factors were assigned to that analyte based upon the system response (peak areas in counts, cts) to a standard vapor of known concentration. Analyte response factors (e.g. counts/ppm), alarm settings, retention time, and other peak attributes were stored in special peak files. Since response factors are GC-method dependent, peak files are linked to GC-method files.

Warm-up time for the zNose® was typically 10 minutes. Calibration only required verification of an n-alkane vapor standard vapor response. Calibration of the instrument required 3-replicate vapor measurements and took less than 5 minutes. Once calibration was complete the response of the system to any analyte (peak) in a test vapor could be displayed with Kovats indices and concentration in user units (e.g. ppm, ppb, pg, ng, etc.) or in detector counts. Run to run measurement time was typically 90 seconds or 45 vapor measurements per hour.

Testing System A

System A was a model 4200 handheld unit with a 1-meter db624 column. A GC-method using a 5°C/sec temperature ramp rate was used. Standard vapors were tested using a 10 second vapor sample which extracted 5 milliliters of vapor with each sampling of the 250 mL bottle. A vent needle allowed air to enter the bottle during sampling and this produced a 2% dilution with each sample taken. Bottle standards were never sampled more than 10 times (16% dilution). A detector temperature of 30°C, representing only moderate sensitivity, was used. The internal valve temperature was set at 50°C and inlet temperature set at 75°C. These system temperatures were adequate since all analytes tested were below C10

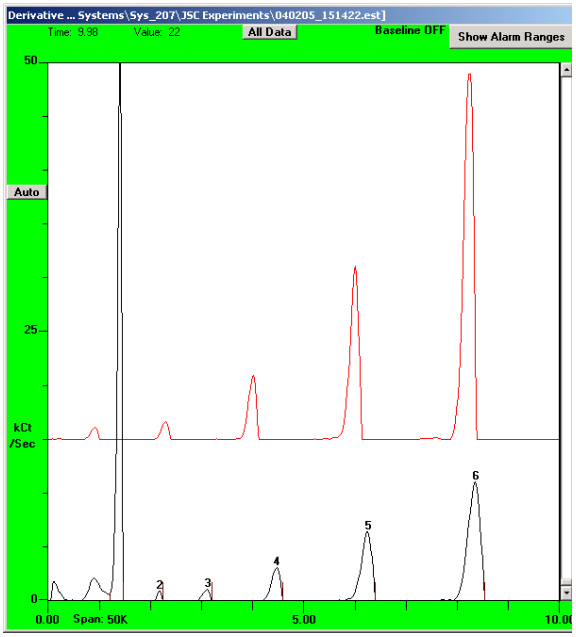


Figure 6- Alkane response using helium (top trace in red) and nitrogen (bottom) carrier gas. Top trace used a 1 second wait state to remove solvent response while bottom trace had no wait state and shows prominent methanol response.

Alkane Response

Alkane vapors, C6 to C10, produced peaks whose retention times were also used as time standards for Kovats indices. The alkane response using nitrogen carrier gas produced only a small shift in retention time. Nitrogen carrier gas did broaden the peaks slightly and reduce the analyte response factors or sensitivity by 40 to 50%.

Chromatogram results using helium and nitrogen carrier gas are shown in the peak file listings shown in Figures 7 and 8. Response factors are in counts per ppm.

Peak File: ... s_207\JSC Experiments\low temp alkanes_5ps2a1b.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor
1	462	4.398	c6	0 Cts	0	Difference	19.83
2	609	3.700	c7	0 Cts	0	Difference	127.75
3	767	2.300	c8	0 Cts	0	Difference	584.49
4	885	2.100	c9	0 Cts	0	Difference	1928.82
5	996	1.400	c10	0 Cts	0	Difference	5006.42

Figure 7- Response parameters using helium carrier gas.

Peak File: ... s_207\JSC Experiments\no-waits_alkanes_5ps2a1b.pkd

File Close Calibration Form

No.	Retention Time	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor
1	1.400	6.600	methanol	0 Cts	0	Area	0.38
2	2.173	4.260	c6	0 Cts	0	Difference	9.42
3	3.109	3.700	c7	0 Cts	0	Difference	78.91
4	4.451	2.300	c8	0 Cts	0	Difference	326.73
5	6.228	2.100	c9	0 Cts	0	Difference	916.96
6	8.322	1.400	c10	0 Cts	0	Difference	2098.84

Figure 8- Response parameters using nitrogen carrier gas

BTE Response

Standard vapors of benzene, toluene, and ethylbenzene, produced peaks whose retention times were quantified and indexed using alkane retention times. The BTE response using nitrogen carrier gas produced only a small shift in retention time. Nitrogen carrier gas broadened the peaks slightly and reduced the analyte response factors or sensitivity by 20 to 30%.

Chromatogram results using helium and nitrogen carrier gas are shown in the peak file listings shown in Figures 10 and 11. Response factors are in counts per ppm

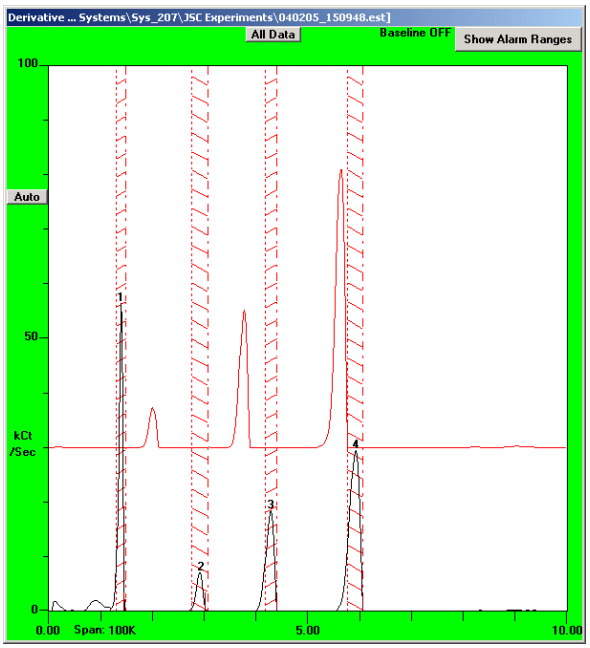


Figure 9- BTE response using helium (top trace in red) and nitrogen (bottom) carrier gas. Top trace used a 1 second wait state to remove solvent response while bottom trace had no wait state and shows prominent methanol response.

Peak File: ... 4\Systems\Sys_207\JSC Experiments\low temp BTE.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor
1	681	5.300	Benzene	0 Cts	0	Difference	86.32
2	785	2.500	Toluene	0 Cts	0	Difference	406.47
3	882	2.500	Ethylbenzene	0 Cts	0	Difference	1083.93

Figure 10- BTE response using helium carrier gas

Peak File: ... \Systems\Sys_207\JSC Experiments\no-waits_ BTE.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor
1	-16	7.000	methanol	0 Cts	0	Area	0.36
2	678	5.300	Benzene	0 Cts	0	Difference	79.88
3	788	2.500	Toluene	0 Cts	0	Difference	314.56
4	881	2.500	Ethylbenzene	0 Cts	0	Difference	706.19

Figure 11- BTE response using Nitrogen carrier gas

Cal2 Response

Standard vapors of 1,2-Dichloroethylene, carbon tetrachloride, trichloroethylene, tetrachloroethene, and o-Xylene, produced peaks whose retention times were quantified and indexed using alkane retention times. The Cal2 response using nitrogen carrier gas produced only a small shift in retention time. Nitrogen carrier gas broadened the peaks slightly and reduced the analyte response factors or sensitivity by 20 to 30%

Chromatogram results using helium and nitrogen carrier gas are shown in the peak file listings shown in Figures 10 and 11. Response factors are in counts per ppm

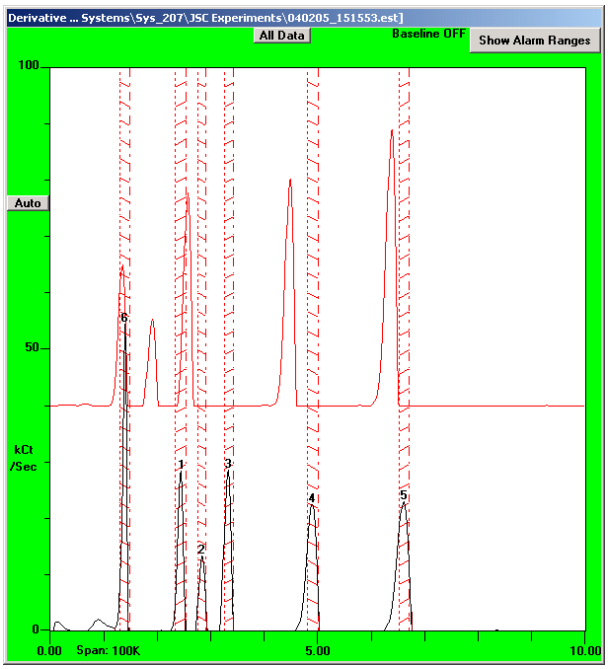


Figure 12-Cal2 response using helium (top trace in red) and nitrogen (bottom) carrier gas. Top trace used a 1 second wait state to remove solvent response while bottom trace had no wait state and shows prominent methanol response

Peak File: ... \Systems\Sys_207\JSC Experiments\low temp cal2.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor
1	631	4.090	1,2 dichloroethylene	0 Cts	0	Area	60.72
2	674	2.630	carbon tetrachloride	0 Cts	0	Area	8.93
3	718	2.370	trichloroethylene	0 Cts	0	Area	276.94
4	825	2.000	tetrachloroethene	0 Cts	0	Area	833.30
5	918	1.400	o-xylene	0 Cts	0	Area	1353.04

Figure 13-Cal2 response using helium carrier gas

Peak File: ... \Systems\Sys_207\JSC Experiments\no-waits cal2.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor
1	-16	6.600	methanol	0 Cts	0	Area	0.33
2	628	4.090	1,2 dichloroethylene	0 Cts	0	Area	59.24
3	670	2.630	carbon tetrachloride	0 Cts	0	Area	5.37
4	716	2.370	trichloroethylene	0 Cts	0	Area	193.91
5	825	2.000	tetrachloroethene	0 Cts	0	Area	529.75
6	918	1.400	o-xylene	0 Cts	0	Area	757.09

Figure 14- Cal2 response using nitrogen carrier gas

Summary System A Test Results

Analyte Kovats indices and response factors in counts per part per million (ppm) are tabulated for System A and shown in Table I.

Table I - Performance Summary for System A

Compound	Helium		Nitrogen	
	Index	*RF*	*Index*	*RF*
Methanol			510	0.38
hexane	600	19.8	600	9.32
1,2 dichloroethylene	631	60.72	628	59.24
carbon tetrachloride	674	8.93	670	5.37
benzene	681	86.32	678	79.88
heptane	700	127.75	700	78.9
trichloroethylene	718	276.9	716	193.9
toluene	785	406.47	788	314.6
octane	800	584.49	800	326.7
tetrachloroethene	825	833.3	825	529.75
ethyl benzene	882	1083.9	881	706.2
nonane	900	1928.8	900	916.96
o-xylene	918	1353	918	767.1
decane	1000	5006	1000	3979.6

Although the use of nitrogen instead of helium did not make a significant change in retention time it did cause a reduction (approximately 30%) in sensitivity. The root cause of the reduction in sensitivity is due to peak broadening and the fact that the detector responded to the net amount of material condensing onto a temperature controlled quartz surface. In general the response factor for the selected analytes is proportional to the analyte's boiling point or molecular weight. For low molecular weight compounds (C6 and below), the minimum detectable signal level was approximately 1 ppm while for heavier compounds up to C10 the minimum detectable signal level was as low as 1 ppb.

It should be noted that a detector temperature of 30^{o}C was used and this represents only moderate sensitivity. Reducing the detector temperature to 0^{o}C could improve sensitivity for all analytes by approximately one order of magnitude.

Testing System B

System B was a model 7100 bench top unit with a 1-meter db624 column. A different GC-method using a 10°C/sec temperature ramp rate was used. Standard vapors were tested using a 10 second vapor sample. A detector temperature of 30°C, representing only moderate sensitivity, was used. The internal valve temperature was set at 50°C and inlet temperature set at 75°C.

Alkane Response

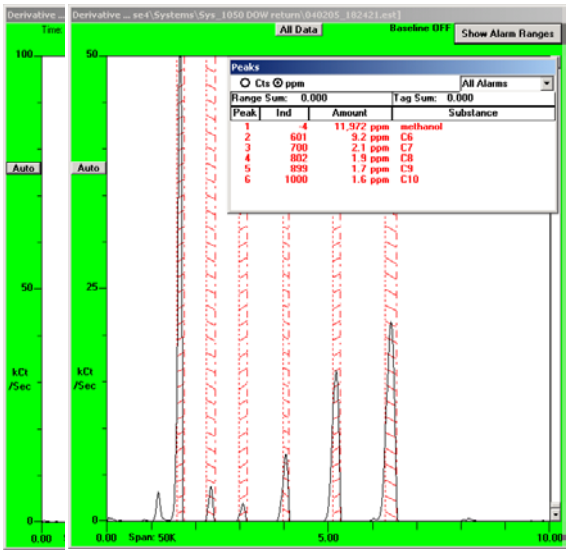


Figure 16- N2 carrier gas

Peak File: ... ms\Sys_1050 DOW return\helium alkanes_10ps2a1b.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor	Tag
1	506	5.100	methanol	0 Cts	0	Difference	0.69	
2	600	4.200	C6	0 Cts	0	Difference	91.43	
3	700	3.200	C7	0 Cts	0	Difference	200.38	
4	800	1.600	C8	0 Cts	0	Difference	947.51	
5	900	1.600	C9	0 Cts	0	Difference	2477.03	
6	1000	1.900	C10	0 Cts	0	Difference	2498.07	

Figure 17-Alkane response (system B) with helium carrier gas

Peak File: ... \Sys_1050 DOW return\nitrogen alkanes_10ps2a1b.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor	Tag
1	0	5.100	methanol	0 Cts	0	Difference	0.57	
2	600	4.200	C6	0 Cts	0	Difference	47.12	
3	700	3.200	C7	0 Cts	0	Difference	116.69	
4	800	1.600	C8	0 Cts	0	Difference	542.05	
5	900	1.600	C9	0 Cts	0	Difference	1671.97	
6	1000	1.900	C10	0 Cts	0	Difference	2987.16	

Figure 18-alkane response system B with nitrogen carrier gas

Cal2 Response

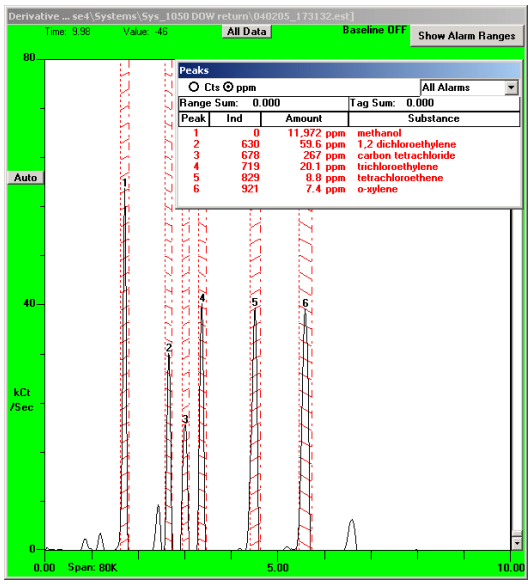


Figure 19-Cal2 response with helium

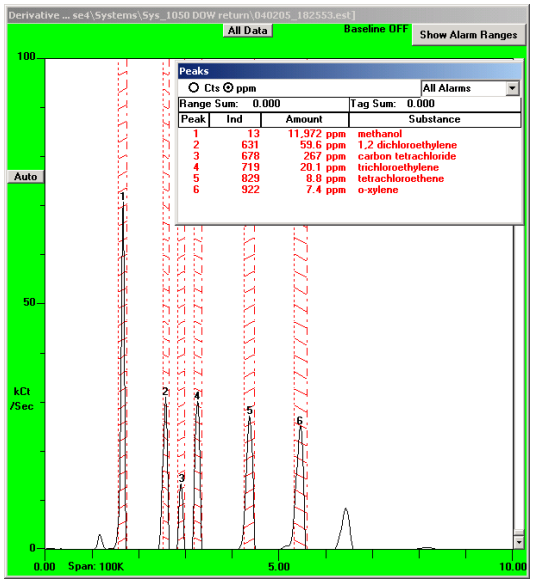


Figure 20-Cal2 response with nitrogen

Peak File: ... Sense4\Systems\Sys_1050 DOW return\helium_cal2.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor	Tag
1	0	5.300	methanol	0 Cts	0	Difference	0.50	
2	630	2.700	1,2 dichloroethylene	0 Cts	0	Difference	58.15	
3	678	2.500	carbon tetrachloride	0 Cts	0	Difference	8.30	
4	719	2.500	trichloroethylene	0 Cts	0	Difference	225.18	
5	829	2.500	tetrachloroethene	0 Cts	0	Difference	600.39	
6	921	2.500	o-xylene	0 Cts	0	Difference	793.71	

Figure 21-Cal2 response with helium carrier gas

Peak File: ... nse4\Systems\Sys_1050 DOW return\nitrogen_cal2.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor	Tag
1	-4	5.300	methanol	0 Cts	0	Difference	0.61	
2	632	2.700	1,2 dichloroethylene	0 Cts	0	Difference	57.90	
3	677	2.500	carbon tetrachloride	0 Cts	0	Difference	5.41	
4	720	2.500	trichloroethylene	0 Cts	0	Difference	181.24	
5	829	2.500	tetrachloroethene	0 Cts	0	Difference	493.64	
6	923	2.500	o-xylene	0 Cts	0	Difference	630.95	

Figure 22-Cal2 response with nitrogen

BTE Response

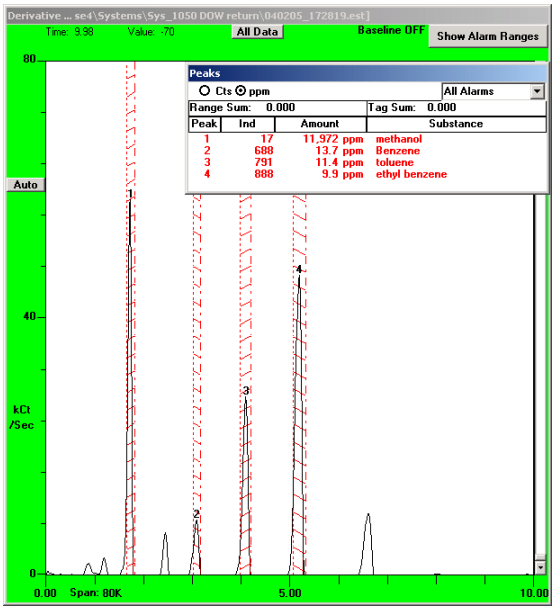


Figure 23-BTE response with helium

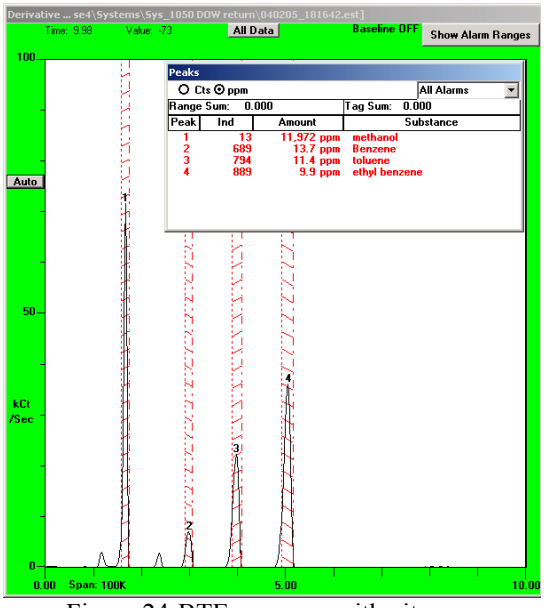


Figure 24-BTE response with nitrogen

Peak File: ... oSense4\Systems\Sys_1050 DOW return\helium_bte.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor	Tag
1	5	5.000	methanol	0 Cts	0	Difference	0.52	
2	688	2.600	Benzene	0 Cts	0	Difference	80.03	
3	791	2.600	toluene	0 Cts	0	Difference	342.32	
4	886	2.500	ethyl benzene	0 Cts	0	Difference	728.71	

Figure 25-BTE response with helium

Peak File: ... ense4\Systems\Sys_1050 DOW return\nitrogen_bte.pkd

File Close Calibration Form

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor	Tag
1	4	5.000	methanol	0 Cts	0	Difference	0.54	
2	688	2.600	Benzene	0 Cts	0	Difference	67.43	
3	795	2.600	toluene	0 Cts	0	Difference	294.61	
4	888	2.500	ethyl benzene	0 Cts	0	Difference	643.17	

Figure 26=BTE response with nitrogen

Summary System B Test Results

Analyte Kovats indices and response factors in counts per part per million (ppm) are tabulated for System B and shown in Table II.

Comparing the results obtained with a handheld (system A, page 7) with those of a bench top model run-

Table II- Performance Summary for System B

Compound	Helium		Nitrogen	
	Index	*RF*	*Index*	*RF*
Methanol	506	0.69	508	0.54
hexane	600	91.43	600	47.1
1,2 dichloroethylene	631	58.1	632	57.8
carbon tetrachloride	674	8.3	677	5.4
benzene	681	80	688	67.4
heptane	700	200.3	700	117
trichloroethylene	718	225	720	181
toluene	785	342	795	295
octane	800	947	800	542
tetrachloroethene	825	600	829	494
ethyl benzene	882	729	888	643
nonane	900	2477	900	1672
o-xylene	918	794	923	631
decane	1000	2498	1000	2987

ning a faster temperature ramp rate (10^{o}C/sec) and no wait states, it can be seen that comparable sensitivity is achieved. The use of nitrogen rather than helium produced the same reduction (approximately 30%) in sensitivity as well and the increase in sensitivity with molecular weight (boiling point) followed a similar pattern. It should be noted that a detector temperature of 30^{o}C was used and this represents only moderate sensitivity. Reducing the detector temperature to 0^{o}C could improve sensitivity for all analytes by approximately one order of magnitude.

System C Model 7100 with 5-meter column

System C was a model 7100 bench top unit with a 5-meter db624 column. A GC-method using a 5°C/sec temperature ramp rate was used and standard vapors were again tested using a 10 second vapor sample and 30°C detector temperature. A comparison of retention time, resolving power, and sensitivity using the longer column is presented. The system performance using nitrogen and helium was also compared.

Long Vs Short Column

Retention time is proportional to the square of column length and resolving power is proportional to the square root of column length and this is evident I the chromatogram comparison of Figure 27.

Physically the peak widths achieved with a long column are larger but the number of plates (resolving power) is much better as can be seen in Table III.

Looking at peak separation normalized to peak width (Figure 27) clearly displays the 2X improvement in resolution achieved with a 5 times increase in column length.

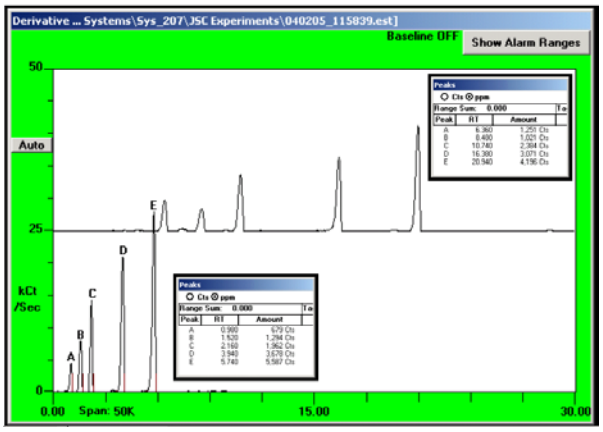


Figure 27- Alkane response using a 1-meter column (lower trace) and a 5-meter (upper trace) db624 column with a 5°C/sec temperature ramp rate.

Table III - Peak width and Plates

Compound	1-Meter Column		5-meter column	
	PW	Plates	PW	Plates
1,2 dichloroethylene	0.2	136	0.33	2036
carbon tetrachloride	0.19	365	0.34	3443
trichloroethylene	0.2	1962	0.31	6813
tetrachloroethene	0.21	1953	0.4	5925
o-xylene	0.31	1888	0.37	17474

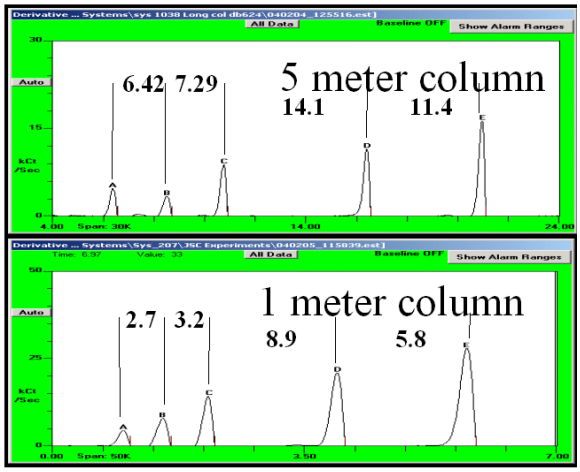


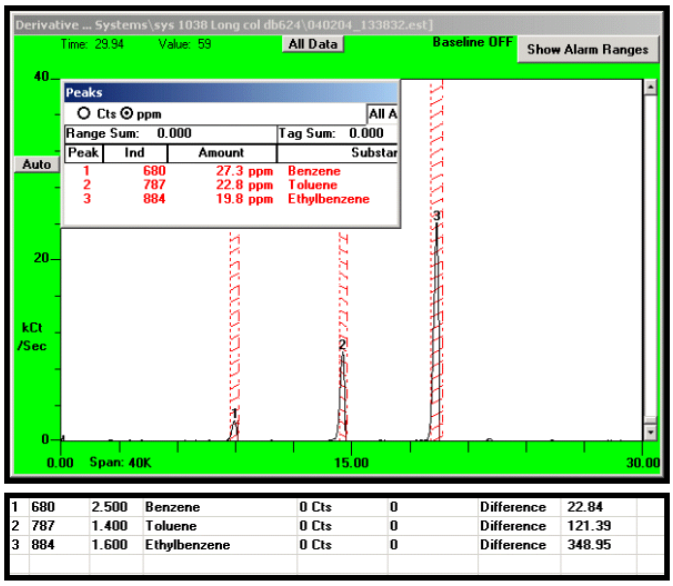
Figure 28- Peak separations normalized to peak width reveal a 2-to-1 improvement in resolving

Sensitivity with Long Column

Sensitivity is reduced with a longer column because of the peak width is increased. Since the detector responds to the net amount of material condensing onto the temperature controlled quartz surface, sensitivity is reduced if peaks are wider.

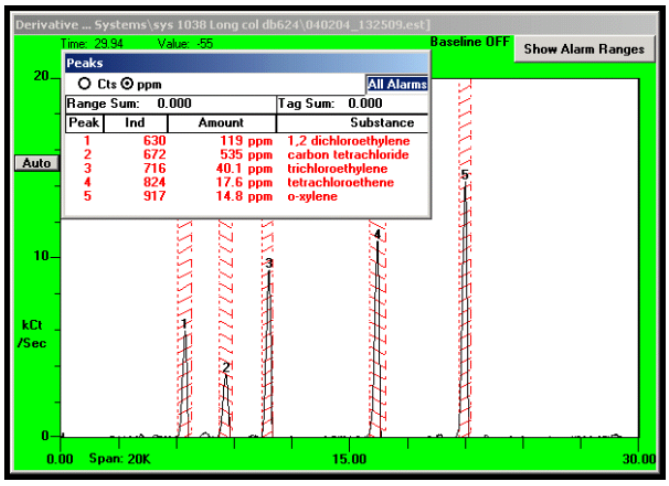
Scale factors for benzene, toluene, and ethyl benzene (Figure 29) are only 25% of what can be achieved with with a 1-meter column (see page 7 and 11).

. A similar reduction in sensitivity occurs for the analytes of Cal2 shown in Figure 30.



1	680	2.500	Benzene	0 Cts	0	Difference	22.84
2	787	1.400	Toluene	0 Cts	0	Difference	121.39
3	884	1.600	Ethylbenzene	0 Cts	0	Difference	348.95

Figure 29- BTE response using 5 meter column, 30°C detector, and 10 second sample time.

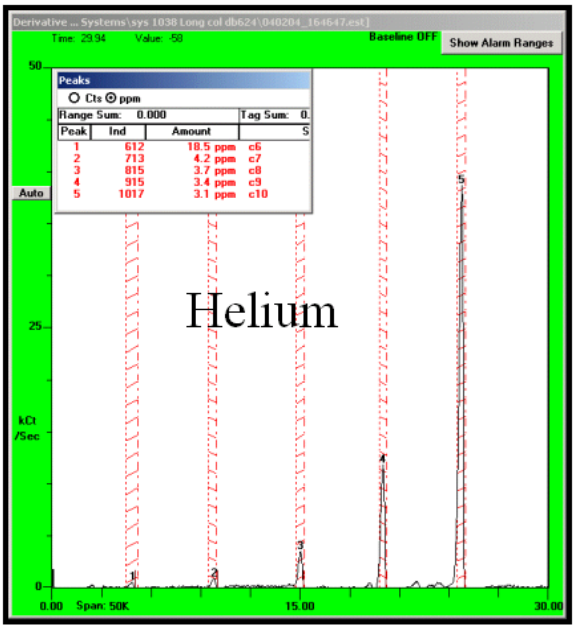


1	629	5.400	1,2 dichloroethylene	0 Cts	0	Difference	13.48
2	671	3.900	carbon tetrachloride	0 Cts	0	Difference	2.00
3	715	2.500	trichloroethylene	0 Cts	0	Difference	62.82
4	824	2.500	tetrachloroethene	0 Cts	0	Difference	172.56
5	917	1.400	o-xylene	0 Cts	0	Difference	265.69

Figure 30- Cal2 response using 5 meter column, 30°C detector, and 10 second sample time.

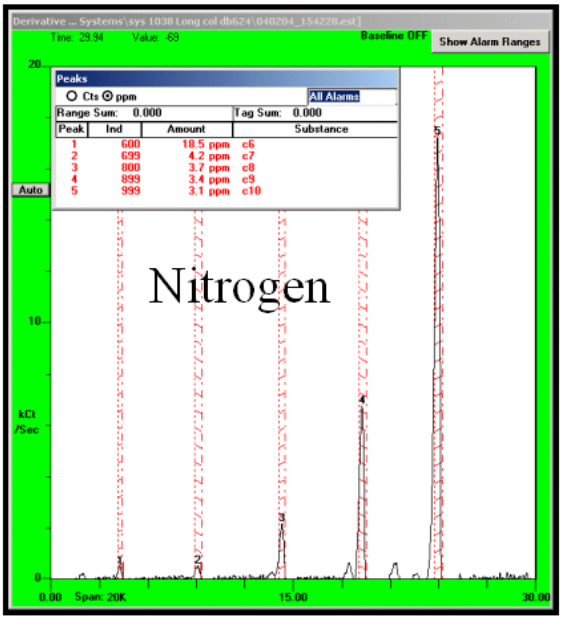
Nitrogen Vs Helium Carrier gas

Using nitrogen instead of helium carrier gas with a longer column produces even more peak broadening and as with the previous results, the sensitivity is reduced. Reduced sensitivity due to peak broadening can be offset to some extent by reducing the detector temperature. This is illustrated in Figures 31 and 31 where a 0°C detector is used.



1	611	7.432	c6	0 Cts	0	Area	7.26
2	711	2.500	c7	0 Cts	0	Area	51.67
3	814	1.752	c8	0 Cts	0	Area	248.33
4	915	1.130	c9	0 Cts	0	Area	942.94
5	1017	0.940	c10	0 Cts	0	Area	3627.01

Figure 31- Alkane response using helium carrier gas, a 5-meter column, and a 0°C detector.



1	600	3.000	c6	0 Cts	0	Area	6.61
2	700	2.500	c7	0 Cts	0	Area	39.47
3	800	1.410	c8	0 Cts	0	Area	173.59
4	900	1.130	c9	0 Cts	0	Area	653.24
5	1000	0.940	c10	0 Cts	0	Area	2087.29

Figure 32-Alkane response using nitrogen carrier gas, a 5-meter column, and a 0°C detector.

Discussion of Results

The objective of this report was to show experimental results using nitrogen carrier gas and to assess performance using a subset of compounds selected from a much larger general list shown in Figure 33. The compounds are sorted by boiling point since this is the natural way to estimate performance with the zNose®. As a general rule the SAW detector used in the zNose® operates by condensing compounds onto a temperature controlled surface e.g. physical absorption. The minimum detector temperature currently available is 0°C so it is not surprising that compounds with boiling points below zero are not detected well if at all. In fact to achieve ppm sensitivity it is necessary to limit compounds to only those with boiling points above 30°C. Compounds such as mercury with boiling points above 350°C are really not volatile. Furthermore they will not pass through a 200°C zNose® system.

	BP		BP
ethylene	-103.7	benzene	80.1
bromotrifluoromethane	-57.8	2-emthyl-2-propanol	82.2
carbonyl sulfide	-50.2	tert-butanol	82.2
freon-22	-40.8	1,2 DCe	83.5
perfluoropropane	-36.7	trichloroethylene	86.7
Ammonia	-33	methyl hydrazine	87.8
freon-12	-29	triethylamine	89
formaldehyde	-19	heptane	98
vinyl chloride	-13.9	gluteraldehyde	101
trimethylamine	2.9	nitromethane	101.2
freon-21	9	toluene	110.6
acetaldehyde	20.1	hydrazine	113.5
freon-11	23.8	MIBK	117.4
furan	31.4	1-butanol	117.6
dichlroroacetylene	33	hexamethylcyclotrisilane	134
pentane	36	2-ethoxyethanol	135.6
isoprene	39	ethyl benzene	136.2
methylene chloride	39.8	p-xylene	138
acrolein	52.7	m-xylene	139
acetone	56.2	o-xylene	144
chloroform	61.7	diacetone alcohol	166
methanol	64.6	ocatamethylcyclotetrasilane	175
hexane	69	limonene	176
1,1,1 trichloroethane	74.1	propylene glycol	187.6
ethyl acetate	77	ethylene glycol	195
ethanol	78	indole	253
MEK	79.6	mercury	356.5
		decamethycylopentasilane	?
		trimethylsilanol	?

Figure 33- Compounds of Interest