

---

# A More Comprehensive And Sensitive Method For CO<sub>2</sub> Quality Assurance

## Application Note: 202

### Authors

Chris Casteel  
Dan Cardin  
Entech Instruments, Inc  
Simi Valley, CA 93065

### Abstract

A technique for the comprehensive analysis of contaminants in Carbon Dioxide has been developed which quantifies a wide range of compounds that previously required multiple methods. Samples are collected in ultra inert fused silica lined stainless steel canisters for subsequent GC/MS analysis of most compound classes including aldehydes, ethers, ketones, alcohols, mercaptans, sulfides, hydrogen sulfide, and various classes of hydrocarbons and halocarbons. Detection levels are 10-100 times lower than current methods, allowing off-flavor and potentially toxic compounds to be monitored at levels which might affect product quality. Through sample preconcentration, LOD's in the sub-ppb range are easily achieved. Fused silica coating of the sampling container, sampling pathway, and sample inlet help to minimize contact with reactive surfaces, thus insuring sample integrity. The inertness of these surfaces acts to further reduce detection limits while allowing investigation of other compound classes for which no previous methodology has been developed. Finally, this



method is readily adaptable to other areas of quality control including testing of product reagents, packaging, and the final product. Multi-sample automation is available to reduce the cost associated with on-going Quality Assurance Programs.

### Introduction

As a multi billion-dollar/year industry, beverage manufacturers' success depends on product development and quality assurance. Contamination events of the past have raised serious questions with both regulatory agencies and consumers. The Food and Drug Administration (FDA) requires all manufacturers to regularly test their products for potentially harmful contents. The FDA monitors compliance by performing site audits and random testing of their own. These measures help to minimize potential dangers to consumers. However, discovering a problem at the final product stage results in reduced productivity and the loss of

The entire product, including materials and ingredients that did not originally contain the offending odors or contaminants. A more prudent approach involves testing of the starting materials before they are actually combined with and contaminate other ingredients. As an important ingredient in a wide variety of beverages, CO<sub>2</sub> testing is a good place to begin.

Carbon Dioxide is used to provide effervescence and mild acidity that in-turn provides some protection against microbial growth.<sup>1</sup> Since the sources for CO<sub>2</sub> can vary greatly, the potential for undesirable or harmful contamination is much greater than with most other ingredients. Contamination can occur from the initial CO<sub>2</sub> source as well as purification, delivery, and storage processes. Due to the number of different contaminants, several methods have been developed to monitor purity. Each method is specific to a certain number or class of contaminants. These methods are used to monitor voluntary guidelines for CO<sub>2</sub> quality. The criteria for determining these guidelines are based on observed sensory effects, known process contamination, or regulatory enforcement. Unfortunately, these methods are often not sensitive enough to detect levels that could be harmful or which may affect product quality. In addition, performing several tests to cover the range of suspected contaminants is costly and time consuming.

In general, non-mass spectrometer based detectors produce small voltage variations as compounds pass through them. Different detectors vary in response, based on the type of compound or compound class. The more specific/sensitive to a certain class of compounds the detector is, the fewer classes of compounds to which it will respond. Conversely, the more classes of compounds the detector responds to, the more prone it is to co-elutions and other chemical noise. Mass spectrometers, however, can detect a wide range of compounds with high specificity and relatively good sensitivity. They are limited by their reduced dynamic range and possible matrix interference from CO<sub>2</sub> and water. By employing a sample inlet system that

reproducibly and quantitatively introduces small to large sample volumes, the method dynamic range can be significantly increased. Similarly reducing or eliminating CO<sub>2</sub> and water interference allows the mass spectrometer to become more effective for high CO<sub>2</sub>/high humidity samples. With the right sample introduction technique, the GC/MS becomes an extremely powerful tool for quantitative analysis and qualitative identification of a diverse range of contaminants.

Sample integrity is best assured by introducing the sample directly from the source to the analytical system. Because analytical systems are rarely this portable, other means of bringing the sample to the equipment is necessary. Concentration onto sorbent media is made possible due to sample interactions with the media. Subsequent extraction from the media often introduces artifacts from the media or the extraction process itself. Artifacts interfere with the analysis and can raise detection limits. The reactivity of some of the potential contaminants is what prompted the ISBT to require all sample pathways to be deactivated. It only follows that the sampling container should likewise be deactivated and non-adsorptive.

The use of Silonite coated mini-cans offers the best solution to these requirements. The Silonite process deposits a uniform layer of fused silica onto stainless steel surfaces. The small size of the mini-can facilitates easy set-up and economical transport. The 400 ml capacity is more than enough to meet the detection limits necessary. Should lower detection limits be required, 1.0 Liter, 2.7 Liter, 3.2 Liter, and 6.0 Liter canisters are available with this coating. This coating is likewise deposited on all surfaces of the sample pathway of the 7100A Preconcentrator.

## **Experimental Section**

EPA Method TO-15 standards containing 65 different aromatic, halogenated, and oxygenated compounds were prepared in 0.4 Liter Entech Minicans (29-MC400L). The standards were prepared at 6 different

concentrations using an Entech 4600 Dynamic Diluter, 1.0 ppm Spectra Gas stock cylinders, a 5 ppm Sulfur standard from HP Gas Products, a 1-5 ppm carbonyl standard from Apel-Riemer Environmental, and CO<sub>2</sub> from Airgas.

## Sampling equipment for CO<sub>2</sub>



*Pressure Reducing Sampler For Nupro Valve Cans*



*Pressure Reducing Sampler For QC Valve Cans*



*621 6 Liter Canister With Nupro Valve*



*MC400L MiniCan With QC Valve*

## Analytical System

GCMS Inlet System: 7100 Preconcentrator and 7032L 21 Position Autosampler (Entech Instruments, Inc.)

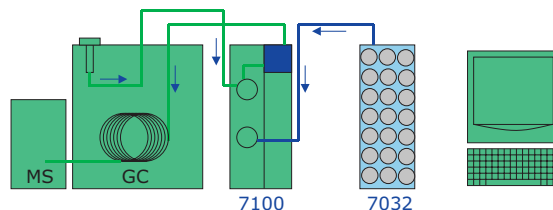
7100 Mode of Operation: Microscale Purge and Trap

GCMS: Agilent 6890/5973N (Palo Alto, CA)

Column: DB-5MS, 0.32mm ID, 60 m, 1um

Temperature Program: 35C (5 min), 6C/min to 140C, 15C/min to 220C. Hold @ 220C for 3

## Diagram of Analytical Equipment



## Preconcentration and GC/MS Analysis

In order to reach low ppb or ppt detection limits, an aliquot of the CO<sub>2</sub> sample must be concentrated before injection into the GCMS. The concentration procedure eliminates most of the water and CO<sub>2</sub> as these compounds can interfere with GCMS analyses. To minimize interference, a 3 stage-trapping procedure called "Microscale Purge and Trap" was utilized. The first stage (M1) uses a glass bead/Tenax filled trap cooled down to -80°C. As the sample is passed through this trap, the majority of Carbon Dioxide passes through the trap while water, some Carbon Dioxide, and all the Volatile Organic Compounds (VOCs) are condensed onto the glass beads and Tenax. The heavier compounds are trapped onto the glass bead portion while the lighter end including H<sub>2</sub>S and some CO<sub>2</sub> are trapped onto the Tenax. This trap is then warmed to 10C. For dry CO<sub>2</sub> samples, the M1 trap can be desorbed at higher temperatures. A small volume (40 cc) of helium is then back-flushed through M1 to transfer the carbon dioxide and compounds of interest to a second Tenax trap (M2) which has been cooled to -60°C. Most of the water remains condensed on the glass beads in module 1 and is baked off later. Most of the remaining CO<sub>2</sub> passes through the tenax in M2 at -60°C and is pumped away. At -60°C the break through volume for H<sub>2</sub>S is greater than 40cc so it is retained in M2. After transfer to the tenax in M2, an open tubular

third trap (M3) is cooled to  $-170^{\circ}\text{C}$ . M2 is then heated to  $+180^{\circ}\text{C}$  and back-flushed with Helium to transfer the sample from M2 to the pre-column focusing trap (M3). At  $-170^{\circ}\text{C}$  the VOCs and any remaining water and  $\text{CO}_2$  are condensed onto a  $1/32''$  OD Silonite coated stainless steel transfer line to refocus the sample before introduction to the GC. M3 is then rapidly heated to above  $50^{\circ}\text{C}$  to inject the VOCs onto the GC column. The first two traps (M1 and M2) are then baked out to prepare them for the next sample.

As required by the ISBT all sample pathway lines are deactivated. The Silonite gas phase deposition process developed at Entech achieves this deactivation. This inert surface allows reactive compounds such as  $\text{H}_2\text{S}$  and Formaldehyde to be quantitatively transmitted to the analytical system.



## Results and Discussion

A chromatogram of a 40 ppb standard is shown in Figure 1. Observable at the beginning of the run, the  $\text{CO}_2$  has been reduced to a level that it is not a factor in the quantitative analysis of the 68 component polar/non-polar VOC standard. Had  $\text{H}_2\text{S}$  not been a compound of interest, trapping conditions could have been changed to eliminate even more of the  $\text{CO}_2$ . Conditions for these tests were set to quantitatively transfer  $\text{H}_2\text{S}$  while eliminating as much  $\text{CO}_2$  as possible. The quantitative nature of this method was tested by running a 5-point calibration curve.

The results of a 5-point calibration (Table 1) shows the effectiveness in quantifying a wide range of compounds. With a percent relative standard deviation (%RSD) of 8.9%,  $\text{H}_2\text{S}$  is shown to be quantitatively transferred and recovered. A wide range of volatile organics with higher boiling points and varying polarities are similarly transferred and recovered. Although not quite as impressive, the %RSD for Formaldehyde is well within EPA and other method guidelines for limits of precision. Considering that no other method has demonstrated formaldehyde at these levels using underivatized GC injection, this %RSD is quite impressive. Generally another form of trapping called cold trap dehydration (CTD) is recommended for formaldehyde due to its solubility in liquid water. CTD works well with high  $\text{CO}_2$  matrices, but not as well with some of the other compounds. Using CTD, %RSDs below 10% for formaldehyde, and most of the other VOCs listed are readily achieved. The purpose of this test was to show that a wide range of compounds, which otherwise would have taken several analyses, can be tested for in a single analysis.

Table 2 contains the results of a detection limit study performed in a 99+%  $\text{CO}_2$  matrix. Standard criteria for instrument detection limits were applied. This procedure calls for seven replicates of a standard at or near the expected detection limit. The instrument detection limit (IDL) is defined as 3 times the standard deviation of the results for each compound. For this determination, 100 ml of a 68 compound 2.0 ppb standard in  $\text{CO}_2$  was analyzed seven times.

The results in Table 2 show that all IDLs are well below the detection limits currently listed in the ISBT methods. Concentrating a larger volume of sample can lower these detection limits even further. Using this instrumentation, sample volumes up to 1.0 Liter can be concentrated, thereby reducing these detection limits by another order of magnitude, if needed.

The real power in using full scan GC/MS is the ability to reduce or eliminate false positives and to identify unknown peaks. With other techniques, a detector response at a certain time is considered a positive identification of a contaminant. However, this assumes that nothing else in the sample could create a response at that time. Since this isn't always the case, confirmatory analyses using a different column and/or set of conditions would be necessary. GC/MS yields not only time/response data, but also mass spectral data that can be compared against the 100,000+ compound National Institute of Science Technology (NIST) Library to determine the possible identity of the unknown compound. Semi-quantitative results for these non-calibrated responses can also be determined since the Total Ion Current (TIC) produced by most compounds in a mass spectrometer are within a factor of 2-3 of each other.

## Conclusion

Current methodologies only allow Levels of Detection (LOD's) down to 20 ppb<sup>1</sup>. However, compounds such as hydrogen sulfide, mercaptans, and thiophenes have olfactory LOD's down to sub-ppb levels and may alter product quality if not monitored at these levels. Other compounds such as vinyl chloride and 1,3-butadiene may create health hazards unless limited to low or sub-ppb levels. Reaching these LOD's requires the use of more inert sampling media, more inert sample pathways to the analytical instrumentation, and a means of introducing larger volumes of sample without compromising the sample integrity. The Entech 7100A Preconcentor meets these requirements offering improved sensitivity and extended applicability for CO<sub>2</sub> analyses.

By preconcentrating a larger volume of sample before injection into a GC or GC/MS, the 7100A reduces detection limits regardless of what type of detector is used. However, the almost complete elimination of water and CO<sub>2</sub> in the sample allows GC/MS to be used for sensitive, confirmatory detection of target compounds, while offering tentative identification and semi-quantitative analysis of contaminants not included in the calibration mixture. Available automation allows increased sample throughput to make use of analytical instrumentation outside of normal work hours.

## References

1. Carbon Dioxide, International Society of Beverage Technologists (ISBT) March 2001

## Table 1 - T015 Initial Calibration Report

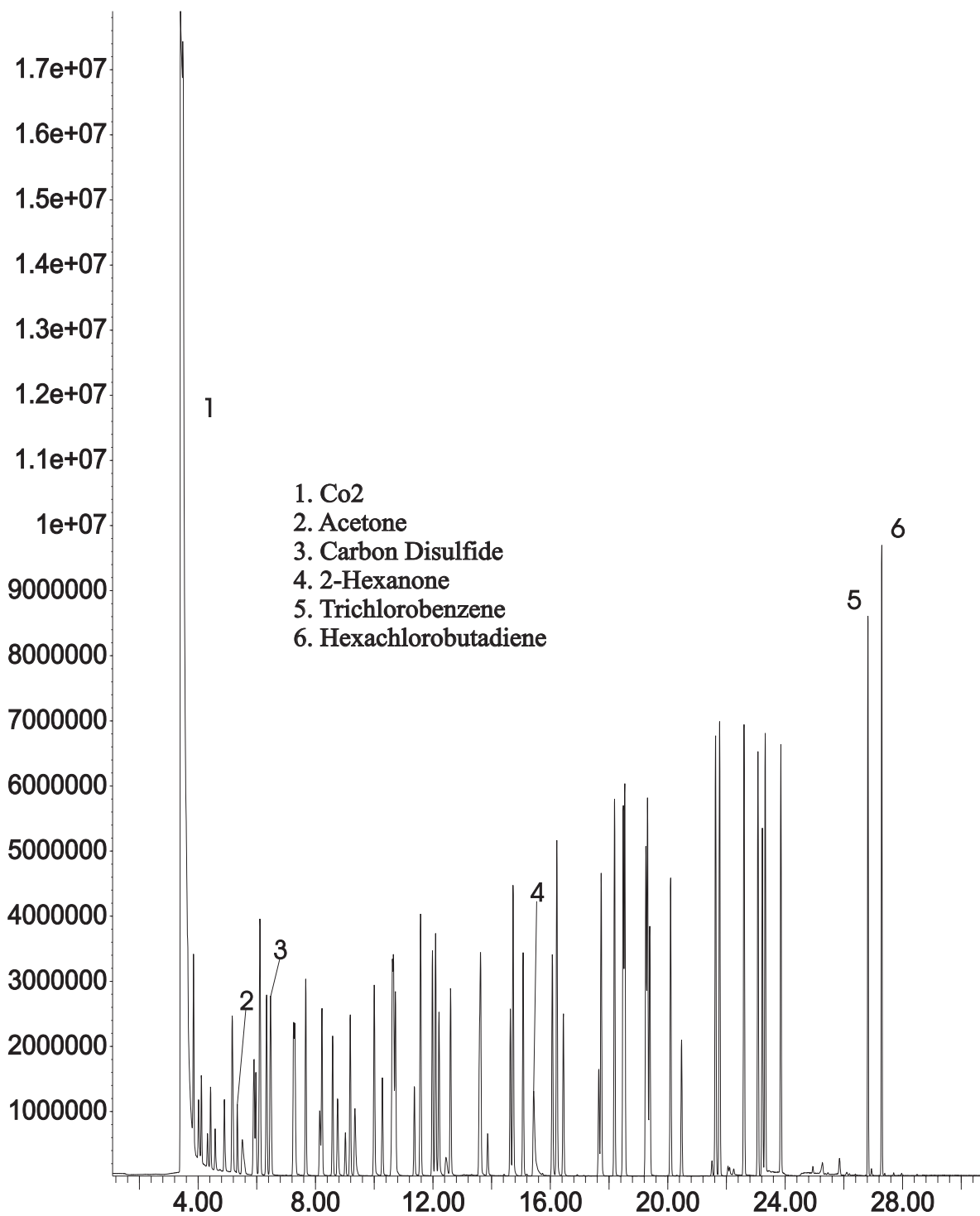
Compound	RRF's						Ave RRF	%RSD
	1	2	5	10	20	40		
Hydrogen Sulfide	0.100	0.120	0.097	0.103	0.116	0.101	0.106	8.90
Formaldehyde	0.057	0.051	0.051	0.039	0.032	0.029	0.043	26.55
Carbonyl Sulfide	1.861	1.601	1.417	1.476	1.307	1.379	1.507	13.26
Propene	0.747	0.539	0.437	0.442	0.447	0.552	0.527	22.58
Dichlorodifluoroethane	1.574	1.262	1.214	1.271	1.340	1.204	1.311	10.51
Chloromethane	1.649	1.417	1.407	1.493	1.508	1.469	1.491	5.87
Methyl Mercaptan	0.998	0.982	0.953	0.970	0.771	0.692	0.894	14.47
Dichlorotetrafluorethane	2.097	1.766	1.740	1.899	1.983	2.712	2.033	17.64
Acetaldehyde	**	4.225	3.176	2.948	2.551	2.256	3.031	24.93
Vinyl Chloride	2.038	1.794	1.826	1.916	1.933	1.828	1.889	4.83
1,3-Butadiene	1.414	1.129	1.235	1.308	1.320	1.231	1.290	5.68
Bromoethane	2.021	1.754	1.751	1.829	1.852	1.775	1.830	5.57
Chloroethane	1.117	0.985	0.966	1.026	1.041	0.985	1.020	5.41
Bromoethene	2.348	2.120	2.136	2.201	2.213	2.031	2.175	4.92
Trichlorofluoromethane	6.742	5.961	6.033	6.177	6.327	5.664	6.151	5.94
Acetone	3.706	3.602	2.809	2.791	2.860	2.687	3.076	14.71
Isopropyl Alcohol	3.223	3.223	3.038	3.096	3.150	3.351	3.187	3.47
1,1-Dichloroethene	3.741	3.380	3.460	3.596	3.578	3.314	3.512	4.47
Dimethyl Sulfide	3.403	2.842	2.821	2.806	2.488	1.957	2.720	17.52
Trichlorotrifluoroethane	5.272	4.646	4.679	4.897	4.818	4.367	4.780	6.32
Allyl Chloride	1.186	1.033	1.023	1.048	1.066	0.963	1.053	7.01
Methylene Chloride	2.585	2.207	2.083	2.101	2.077	1.878	2.155	10.95
Carbon Disulfide	8.845	7.520	6.125	6.469	6.034	5.337	6.722	18.77
trans-1,2-Dichloroethene	3.471	3.126	3.081	3.184	3.188	2.891	3.157	5.97
Methyl tert-Butyl Ether	7.906	6.884	6.848	7.041	7.033	6.419	7.022	6.96
Vinyl Acetate	4.855	4.433	4.397	4.858	4.584	4.241	4.561	5.55
1,1-Dichloroethane	4.500	3.970	4.004	4.117	4.125	3.745	4.077	6.11
2-Butanone	1.224	1.202	1.162	1.214	1.210	1.145	1.193	2.66
Hexane	3.776	3.382	3.376	3.477	3.253	2.966	3.372	7.88
cis-1,2-Dichloroethene	3.292	2.899	2.950	3.069	3.057	2.825	3.015	5.45
Ethyl Acetate	3.929	3.679	3.666	3.822	3.868	3.618	3.764	3.35
Chloroform	5.761	4.917	4.954	5.144	5.146	4.742	5.111	6.91
Tetrahydrofuran	1.121	1.114	1.154	1.146	1.147	1.080	1.127	2.48
1,1,1-Trichloroethane	5.934	5.227	5.326	5.514	5.518	5.074	5.432	5.51
1,2-Dichloroethane	3.528	3.102	3.166	3.275	3.282	3.038	3.232	5.37
Benzene	8.889	7.596	7.735	7.981	7.922	7.299	7.904	6.85
Carbon Tetrachloride	5.744	5.115	5.279	5.468	5.522	5.085	5.369	4.76
2,2,4-Trimethylpentane	2.538	2.190	2.174	2.214	2.268	2.042	2.238	7.38
Heptane	0.673	0.566	0.577	0.580	0.590	0.535	0.587	7.88
Trichloroethene	0.853	0.735	0.737	0.759	0.767	0.693	0.757	7.06
1,2-Dichloropropane	0.625	0.533	0.542	0.556	0.567	0.519	0.557	6.70
Bromodichloromethane	1.326	1.135	1.142	1.168	1.207	1.086	1.177	7.05
cis-1,3-Dichloropropene	1.171	0.994	1.016	1.042	1.065	0.979	1.045	6.64
4-Methyl-2-pentanone	0.799	0.995	0.989	0.995	0.980	0.903	0.944	8.38
trans-1,3-Dichloropropene	0.974	0.851	0.880	0.899	0.923	0.854	0.897	5.20
Toluene	2.552	2.117	2.083	2.115	2.122	1.953	2.157	9.45
1,1,2-Trichloroethane	0.785	0.683	0.683	0.699	0.705	0.649	0.701	6.52
2-Hexanone	0.334	0.466	0.551	0.568	0.541	0.546	0.501	17.79
Dibromochloromethane	1.306	1.137	1.150	1.165	1.228	1.118	1.184	5.96
Tetrachloroethene	1.296	1.081	1.083	1.102	1.106	0.996	1.111	8.93
1,2-Dibromoethane	1.254	1.077	1.086	1.108	1.119	1.025	1.112	6.93
Chlorobenzene	2.141	1.861	1.864	1.906	1.906	1.687	1.893	7.69
Ethylbenzene	3.583	3.085	3.079	3.158	3.133	2.778	3.136	8.25
m-Xylene	2.908	2.523	2.504	2.534	2.467	2.219	2.526	8.75
p-Xylene	2.667	2.393	2.410	2.512	2.307	2.165	2.409	7.13
Styrene	2.210	1.936	1.940	1.988	1.965	1.761	1.967	7.32
o-Xylene	2.999	2.544	2.553	2.606	2.560	2.274	2.589	9.00
Bromoform	1.414	1.250	1.284	1.293	1.397	1.238	1.313	5.71
1,1,2,2-Tetrachloroethane	1.920	1.671	1.648	1.675	1.664	1.463	1.674	8.69
4-Ethyltoluene	3.840	3.363	3.336	3.324	3.330	2.973	3.361	8.23
1,3,5-Trimethylbenzene	3.520	3.002	3.031	3.082	3.007	2.660	3.050	9.02
1,2,4-Trimethylbenzene	3.493	3.039	3.047	3.089	3.027	2.688	3.064	8.36
1,3-Dichlorobenzene	2.359	2.026	2.005	2.019	1.999	1.756	2.027	9.49
Benzyl Chloride	2.692	2.474	2.535	2.522	2.604	2.466	2.549	3.37
1,4-Dichlorobenzene	2.368	2.018	2.016	2.023	1.995	1.758	2.030	9.60
1,2-Dichlorobenzene	2.204	1.877	1.869	1.881	1.863	1.634	1.888	9.64
1,2,4-Trichlorobenzene	2.009	1.778	1.716	1.743	1.561	1.388	1.699	12.35
Hexachlorobutadiene	1.809	1.580	1.562	1.476	1.233	0.992	1.442	19.99

## Table 2 - T015 Detection Limit Study

Compound	Responses (ppbv)							Ave Resp	SD	IDL
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7			
Propene	0.12	0.10	0.08	0.11	0.10	0.09	0.09	0.10	0.01	0.04
Dichlorodifluoroethane	0.11	0.09	0.08	0.10	0.09	0.08	0.07	0.09	0.01	0.04
Chloromethane	0.11	0.12	0.10	0.12	0.08	0.10	0.10	0.10	0.01	0.04
Dichlorotetrafluorethane	0.10	0.09	0.08	0.11	0.10	0.08	0.08	0.09	0.01	0.04
Vinyl Chloride	0.11	0.09	0.08	0.11	0.08	0.08	0.08	0.09	0.01	0.04
1,3-Butadiene	0.10	0.09	0.04	0.10	0.08	0.08	0.08	0.08	0.02	0.06
Bromoethane	0.11	0.08	0.07	0.10	0.07	0.08	0.07	0.08	0.02	0.05
Chloroethane	0.10	0.09	0.07	0.10	0.07	0.08	0.08	0.08	0.01	0.04
Bromoethene	0.09	0.08	0.07	0.08	0.05	0.07	0.07	0.07	0.01	0.04
Trichlorofluoromethane	0.14	0.08	0.07	0.09	0.07	0.07	0.06	0.08	0.03	0.08
Acetone	0.10	0.12	0.10	0.13	0.07	0.10	0.10	0.10	0.02	0.06
1,1-Dichloroethene	0.11	0.09	0.08	0.11	0.10	0.08	0.07	0.09	0.02	0.05
Trichlorotrifluoroethane	0.12	0.09	0.08	0.11	0.08	0.09	0.08	0.09	0.02	0.05
Allyl Chloride	0.20	0.10	0.09	0.12	0.08	0.10	0.09	0.11	0.04	0.12
Methylene Chloride	0.29	0.25	0.24	0.20	0.09	0.20	0.13	0.20	0.07	0.21
Carbon Disulfide	0.11	0.15	0.25	0.27	0.20	0.24	0.24	0.21	0.06	0.18
trans-1,2-Dichloroethene	0.11	0.09	0.08	0.12	0.24	0.09	0.08	0.12	0.06	0.17
Methyl tert-Butyl Ether	0.11	0.11	0.08	0.11	0.08	0.09	0.08	0.09	0.02	0.05
Vinyl Acetate	0.11	0.09	0.08	0.07	0.08	0.09	0.08	0.09	0.01	0.04
1,1-Dichloroethane	0.11	0.09	0.08	0.11	0.08	0.09	0.08	0.09	0.01	0.04
2-Butanone	0.15	0.11	0.09	0.11	0.08	0.10	0.08	0.10	0.02	0.07
Hexane	0.10	0.09	0.07	0.10	0.08	0.08	0.08	0.09	0.01	0.03
cis-1,2-Dichloroethene	0.10	0.09	0.08	0.11	0.08	0.08	0.08	0.09	0.01	0.04
Ethyl Acetate	0.11	0.10	0.08	0.10	0.08	0.08	0.08	0.09	0.01	0.04
Chloroform	0.10	0.09	0.08	0.11	0.08	0.08	0.07	0.09	0.01	0.04
Tetrahydrofuran	0.10	0.12	0.08	0.11	0.08	0.10	0.09	0.10	0.01	0.04
1,1,1-Trichloroethane	0.10	0.09	0.07	0.10	0.07	0.08	0.07	0.08	0.01	0.04
1,2-Dichloroethane	0.12	0.09	0.07	0.10	0.07	0.07	0.07	0.08	0.02	0.06
Benzene	0.11	0.10	0.08	0.12	0.09	0.09	0.09	0.10	0.01	0.04
Carbon Tetrachloride	0.11	0.09	0.08	0.10	0.07	0.08	0.07	0.09	0.02	0.05
Cyclohexane	0.11	0.10	0.09	0.12	0.09	0.09	0.09	0.10	0.01	0.04
2,2,4-Trimethylpentane	0.10	0.09	0.08	0.11	0.08	0.08	0.08	0.09	0.01	0.04
Heptane	0.11	0.09	0.08	0.11	0.07	0.08	0.07	0.09	0.02	0.05
Trichloroethene	0.11	0.09	0.08	0.11	0.08	0.08	0.08	0.09	0.01	0.04
1,2-Dichloropropane	0.10	0.09	0.08	0.11	0.08	0.08	0.08	0.09	0.01	0.04
Bromodichloromethane	0.10	0.08	0.07	0.10	0.07	0.07	0.07	0.08	0.01	0.04
cis-1,3-Dichloropropene	0.08	0.09	0.08	0.11	0.08	0.08	0.08	0.09	0.01	0.03
4-Methyl-2-pentanone	0.10	0.11	0.08	0.08	0.09	0.10	0.09	0.09	0.01	0.03
trans-1,3-Dichloropropene	0.11	0.09	0.08	0.11	0.07	0.08	0.07	0.09	0.02	0.05
Toluene	0.11	0.10	0.08	0.12	0.08	0.09	0.08	0.09	0.02	0.05
1,1,2-Trichloroethane	0.10	0.09	0.08	0.11	0.08	0.09	0.08	0.09	0.01	0.03
2-Hexanone	0.10	0.12	0.10	0.10	0.11	0.12	0.10	0.11	0.01	0.03
Dibromochloromethane	0.12	0.08	0.07	0.10	0.07	0.07	0.07	0.08	0.02	0.06
Tetrachloroethene	0.11	0.10	0.08	0.12	0.08	0.08	0.08	0.09	0.02	0.05
1,2-Dibromoethane	0.11	0.09	0.08	0.11	0.08	0.08	0.08	0.09	0.01	0.04
Chlorobenzene	0.11	0.10	0.08	0.12	0.08	0.09	0.08	0.09	0.02	0.05
Ethylbenzene	0.11	0.09	0.08	0.12	0.08	0.09	0.09	0.09	0.02	0.05
m-Xylene	0.10	0.09	0.08	0.10	0.09	0.08	0.07	0.09	0.01	0.03
p-Xylene	0.11	0.10	0.08	0.11	0.08	0.08	0.08	0.09	0.01	0.04
Styrene	0.11	0.10	0.08	0.11	0.08	0.08	0.08	0.09	0.01	0.04
o-Xylene	0.11	0.09	0.08	0.12	0.08	0.09	0.08	0.09	0.02	0.05
Bromoform	0.10	0.10	0.08	0.10	0.07	0.08	0.07	0.09	0.01	0.04
1,1,2,2-Tetrachloroethane	0.11	0.11	0.09	0.12	0.08	0.09	0.08	0.10	0.02	0.05
4-Ethyltoluene	0.12	0.10	0.08	0.12	0.09	0.09	0.08	0.10	0.02	0.05
1,3,5-Trimethylbenzene	0.12	0.11	0.09	0.12	0.08	0.09	0.08	0.10	0.02	0.05
1,2,4-Trimethylbenzene	0.12	0.11	0.09	0.12	0.09	0.09	0.09	0.10	0.01	0.04
1,3-Dichlorobenzene	0.13	0.10	0.09	0.12	0.09	0.09	0.09	0.10	0.02	0.05
Benzyl Chloride	0.11	0.11	0.09	0.11	0.08	0.08	0.07	0.09	0.02	0.05
1,4-Dichlorobenzene	0.12	0.11	0.08	0.12	0.09	0.09	0.09	0.10	0.02	0.05
1,2-Dichlorobenzene	0.13	0.11	0.09	0.12	0.09	0.10	0.09	0.10	0.02	0.05
1,2,4-Trichlorobenzene	0.17	0.16	0.14	0.15	0.13	0.13	0.11	0.14	0.02	0.06
Hexachlorobutadiene	0.13	0.13	0.10	0.12	0.10	0.10	0.09	0.11	0.02	0.05

# 68 Component Polar/Nonpolar VOC Standard @ 40 ppb

Abundance



Time-->

Figure 1