	# VOCAM Heated PID-GC For Distributed VOC Monitoring	Defiant Technologies info@defiant-tech.com 1-505-999-5880 **www.defiant-tech.com**

Introduction to VOCAM

There is an emerging need for remote monitoring of volatile organic compounds (VOCs) in environments that may contain large concentrations of low vapor pressure compounds. There is a growing need for continuous monitoring of benzene at refinery fence-lines and fracking sites both for regulatory compliance and community monitoring. This can be a difficult environment in which to operate a portable GC system or a handheld PID as either may require more frequent cleaning cycles.

Defiant Technologies is introducing a solution, the VOCAM. The VOCAM (**figure 1**) is based on Defiant's MEMS preconcentrator, MEMES gas chromatograph, and a heated PID. Regenerable scrubbers take in ambient air and provides dry air that greatly reduces the ambient organic compounds that may be present where the system is deployed.

Figures 2 shows how VOCAM can be deployed in the field and how system integrators combine VOCAM with other systems to provide rich content to their end-customers. **Figure 3** shows VOCAM as part of a system of systems. VOCAM provides specific analyte information like benzene concentrations while other sensors may add information like weather, particle size, total VOC, or a variety of other data.

The new heated PID and regenerable scrubbers enable the VOCAM to operate in dirty environments like those encountered at a refinery fence-line where one may wish to monitor benzene only even with a background with large concentrations of low vapor pressure VOCs.

VOCAM features

- MEMS Preconcentrator
- MEMS Gas chromatograph with a programmable temperature controller
- Heated Photoionization Detector
- Chromatographic data backup on SD card
- Serial data communication for command and acquisition
- Regenerable organic scrubber for carrier gas
- Replaceable humidity scrubber for carrier gas
- 15000 hour Pumps for carrier gas and sample collection
- 12V input
- Total System Mass of 1.02 kg
- 10.6eV PID Lamp

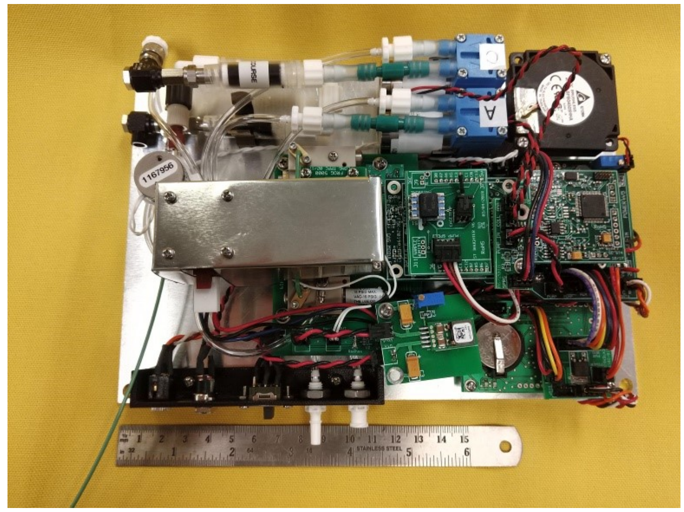

Figure 1: VOCAM Product

Figure 2: VOCAM is shown integrated with sensors for wind-speed, direction, and total VOCs.

Figure 3: The image above shows how VOCAM is deployed with other sensors.

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Heated PID

The heated PID can be seen in figure 4. The lamp is heated and the electronics to drive the lamp and detect target analytes are separated allowing it to operate at ambient conditions. Scrubbing ambient air to produce a clean dry carrier gas doesn't provide sufficient protection for a system intended to operate continuously in the field. Heating the PID enables the system to clear itself of all of the analytes desorbed into the system from its preconcentrator. Heating the PID enables those compounds to travel through the detector and minimize condensation. The detector also defines the analytical path enhancing chromatographic separations by narrowing chromatographic peaks. This is shown clearly on page 4.

Demonstrating VOCAM's Capabilities

To demonstrate its effectiveness, Defiant performed a series of experiments.

In the first laboratory trial, a VOCAM was calibrated and then subjected to a constant background of a low vapor pressure compound, 1,2,3-trimethylbenzene (1,2,3-TMB) to simulate a potential complex operating environment. **Figure 5** shows an example of one of the calibration data points which is also one of the concentrations that was checked daily.

After the initial calibration, VOCAM continuously sampled a vapor stream of 110ppbv 1,2,3-TMB. An example of a common exposure can be viewed in **figure 6**. The exposures continued until the system was interrupted the following day for a calibration check sample.

Each day, the VOCAM was removed and a full set of calibration concentrations were introduced and recorded as calibration checks. Then the system was operated with a constant background of the test low vapor pressure interfering compound, 1,2,3-TMB. This was repeated each day until the system dropped below 75% recovery.

At the end of the study, the VOCAM had performed 1800 analysis cycles with 110ppbv 1,2,3-trimethylbenzene in the background and stayed within ±25% of its initial calibration.

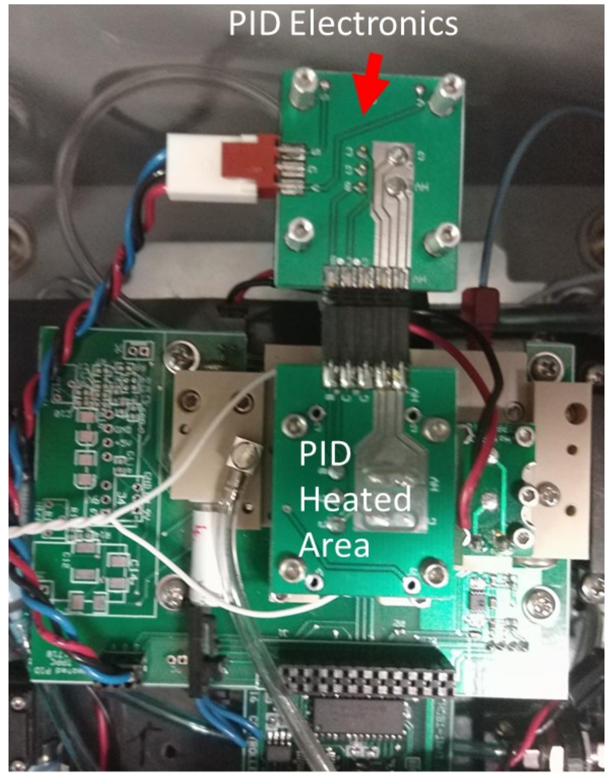

Figure 4: Above is a picture of the new heated PID

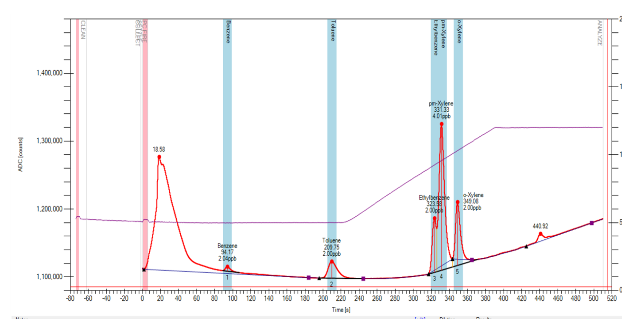

Figure 5: Above is a picture of an analysis of 2ppbv BTEX in air.

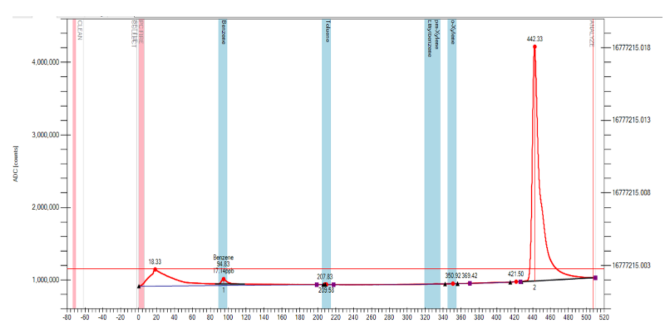

Figure 6: Above is a picture of an analysis of 110ppbv 1,2,3-trimethylbenzene in air.

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Demonstrating VOCAM's Capabilities contued: The VOCAM was initial calibrated with 5 different concentrations of BTEX at Defiant Technologies using calibration gas cylinder certified by the manufacturer and diluted using mass flow controllers. Below are graphs and data points for the low calibration point , 2.0ppbv and the mid calibration point, 82, ppbv. Data was collected for each analyte benzene, toluene, ethylbenzene, and xylenes. Only benzene is shown in this summary. As can be seen in the data below, the system provided results at its low and mid calibration points within 25% of the original calibration.

Introduced (ppbv)	Calculated (ppbv)	%Rec	Time Since Calibration
2.00	1.89	95%	0 Days 0 Hours
2.00	2.40	120%	0 Days 15 Hours
2.00	2.36	118%	1 Days 15 Hours
2.00	2.42	121%	2 Days 15 Hours
2.00	2.39	120%	3 Days 16 Hours
2.00	2.27	114%	4 Days 15 Hours
2.00	2.10	105%	5 Days 14 Hours
2.00	1.80	90%	6 Days 23 Hours
2.00	1.69	85%	7 Days 15 Hours
2.00	1.70	85%	8 Days 15 Hours
2.00	1.81	91%	9 Days 15 Hours
2.00	1.70	85%	10 Days 16 Hours
2.00	1.56	78%	11 Days 16 Hours
2.00	1.53	77%	12 Days 16 Hours
2.00	1.50	75%	14 Days 16 Hours

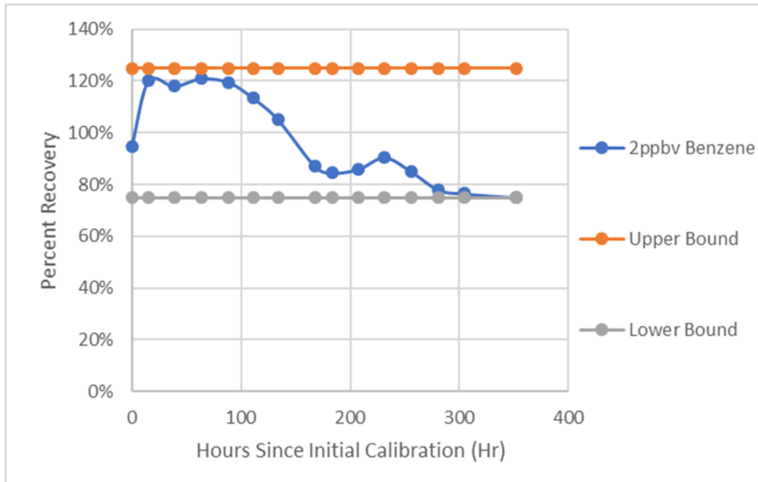

Figure 7: Above is a graph of the percent recovery for 2ppbv benzene checked daily between numerous exposures to a low vapor pressure compound. To the left is the raw data for that graph.

Introduced (ppbv)	Calculated (ppbv)	%Rec	Time Since Calibration
82	80.9	99%	0 Days 0 Hours
82	93.5	114%	0 Days 15 Hours
82	100.1	122%	1 Days 15 Hours
82	101.4	124%	2 Days 15 Hours
82	95.2	116%	3 Days 17 Hours
82	91.7	112%	4 Days 15 Hours
82	85.9	105%	5 Days 14 Hours
82	73.4	89%	6 Days 23 Hours
82	76.4	93%	7 Days 16 Hours
82	74.1	90%	8 Days 15 Hours
82	75.7	92%	9 Days 15 Hours
82	73.0	89%	10 Days 16 Hours
82	70.7	86%	11 Days 17 Hours
82	66.4	81%	12 Days 16 Hours
82	63.0	77%	14 Days 16 Hours

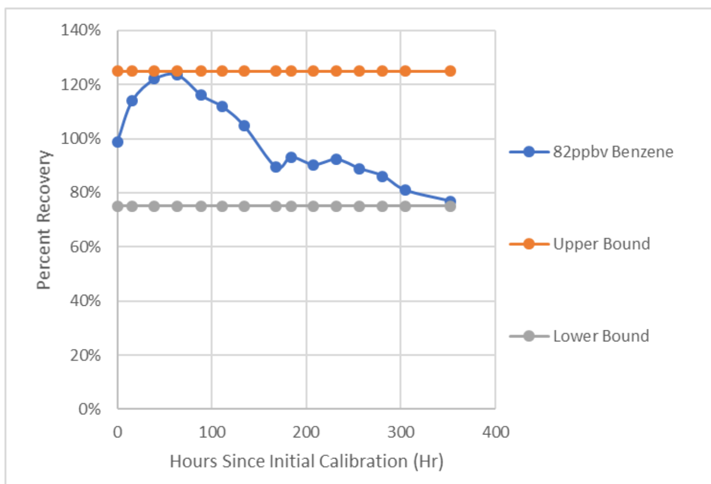

Figure 8: Above is a graph of the percent recovery for 82ppbv benzene checked daily between numerous exposures to a low vapor pressure compound. To the left is the raw data for that graph.

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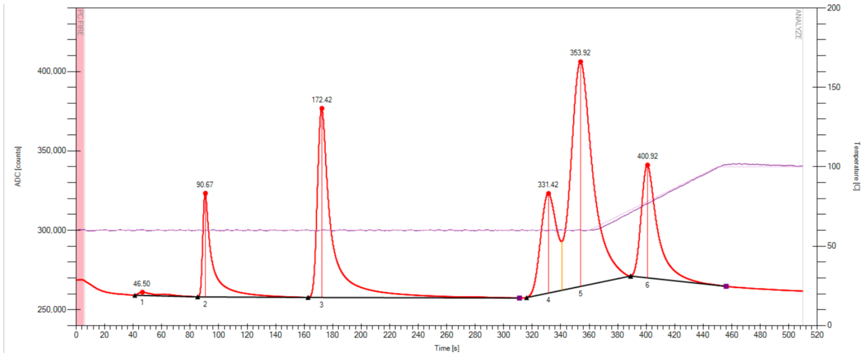

Figure 9: The chromatogram above is a sample from a production FROG-5000 unit. This product provides good separations for its purpose.

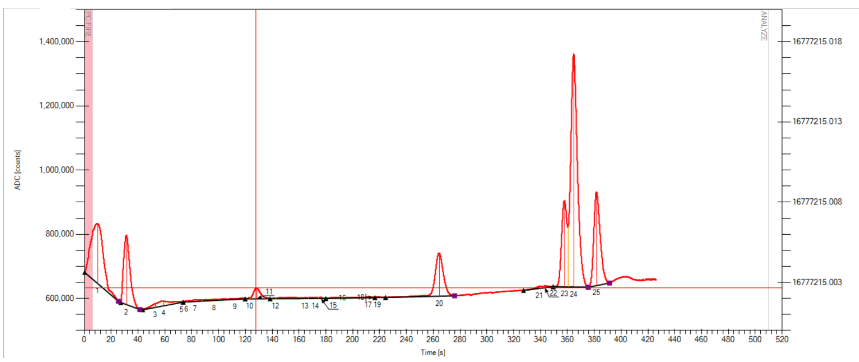

Figure 10: Is a calibration check performed in the field. Note the full width half max of the chromatographic peaks.

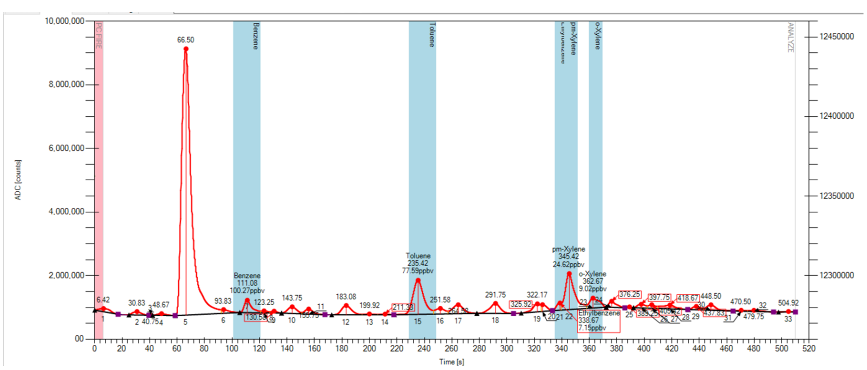

Figure 11: Above is a chromatogram from a field test near a hydraulic fracturing site.

Chromatographic performance:

Defiant produces a number of chromatographic products. Each provides sufficient separations for applications. **Figure 9** shows a typical chromatogram from product minimizing power consumption for longer battery life. The results are impressive as this is the smallest commercial gas chromatograph and the world's first MEMS based commercial GC.

VOCAM takes this a step further. While the GC column is the same, the detector is heated to minimize band broadening due to condensation and minimizes dead volume to complement that feature. **Figure 10** shows a calibration check point analyzed in the field. The results are clear, the compounds most like to band broaden across a cold detector or from unswept dead volume meaning the late eluting chromatographic are far narrower. This feature exposes the true power of Defiant's high aspect ratio MEMS GC column.

Figure 11 shows a chromatogram of an air sample taken near a well head. There are 30+ peaks separated in this chromatogram thanks to minimizing the dead volume in the detector and heating the detector. BTEX is readily distinguished from the other non-target compounds in the background.

For more information about VOCAM, serial commands, and data output description, please contact Defiant Technologies, Inc. at 505-999-5880 or visit our website at www.defiant-tech.com.