MODES & APPLICATIONS FOR THE MULTIRAE BENZENE

INTRODUCTION

Benzene is a very well-known human carcinogen that is widely distributed throughout nature (coal, crude oil, gas and gas condensate). In most fuel products (gasoline, diesel, jet fuel), it exists in concentrations of up to several percent, by volume (vol%). Benzene is a very important industrial chemical, as well. It belongs to the BTEX aromatic family and is a liquid with a rather high vapor pressure. Due to its hazardous properties, Cal/OSHA set its PEL (Personal Exposure Limit) as 1 ppm of TWA and 5 ppm of STEL (Short Term Exposure Limit).[1] ACGIH recommends even more strict limits of 0.5 and 2.5 ppm, respectively.[2] There are several portable products on the market (from RAE Systems, IonScience, Dräger) that are able to measure such low concentrations of benzene, but only the MultiRAE Benzene combines the ability to make quick benzene-specific assessment ("snapshot") measurements with the advantages of a versatile multi-gas monitor (up to six gas sensors) with real-time wireless capability. It can support more than 20 intelligent interchangeable sensor options.

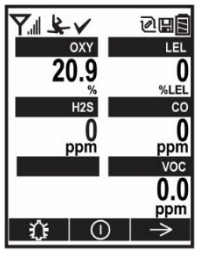
MultiRAE Benzene with RAE-Sep Tube Cartridge

Note: This Technical Note applies only to the MultiRAE Benzene monitor. For information regarding the UltraRAE 3000, refer to RAE Systems Technical Note TN-127: "Benzene-Specific Measurements In Petroleum Hydrocarbons Using The RAE Systems UltraRAE 3000."

INSTRUMENT AND CARTRIDGE

The MultiRAE Benzene is designed specifically for use with the replaceable benzene-specific RAE-Sep Tube Cartridge, which comprises six individual RAE-Sep tubes.

The MultiRAE Benzene has two modes: TVOC (Total Volatile Organic Compounds) mode and Benzene mode. When used in TVOC mode, its display shows all sensor readings continuously.

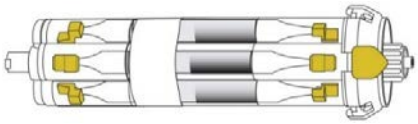


TVOC Mode

Benzene Mode

When the instrument is in benzene mode, the display prompts for snapshot sampling. (Refer to the MultiRAE User's Guide for details on managing, calibrating, and measuring in both TVOC and Benzene modes[3].) To perform snapshot compound-specific (benzene) measurement in addition to general VOC measurement requires a RAE-Sep Tube Cartridge (available in packs of six: P/N M01-0312-000).

Note: Each tube should be used for one measurement only.



RAE-Sep Cartridge

The RAE-Sep Tube Cartridge is designed to provide six one-time specific measurements of benzene. This cartridge has unique properties and performance features not found in other monitors' separation tube configurations. It has been designed to provide accurate, benzene-only measurement and has only been evaluated and tested on the MultiRAE Benzene monitor.

Note: Failure to use the MultiRAE Benzene monitor with the RAE-Sep Tube Cartridge will result in inaccurate detection or measurement, which may include the failure to detect benzene and possible serious injury or death.

For proper cartridge operation and replacement, refer to the document "RAE-Sep Tube Cartridge For MultiRAE Benzene."[4]

Some measurable parameters of the instrument are presented below. Refer to the MultiRAE Benzene datasheet for comprehensive sensor specification data.[5]

Sensor/Mode	Range	Resolution
9.8eV for use in TVOC mode	10 ppb to 2,000 ppm	10 ppb
9.8eV for use in Benzene mode (with RAE-Sep Tube Cartridge)	0.1 to 200 ppm	0.1 ppm

MULTIRAE BENZENE-SPECIFIC MEASUREMENT PRINCIPLE

In Benzene mode, the monitor is designed to make specific benzene measurements. This is achieved via these two approaches:

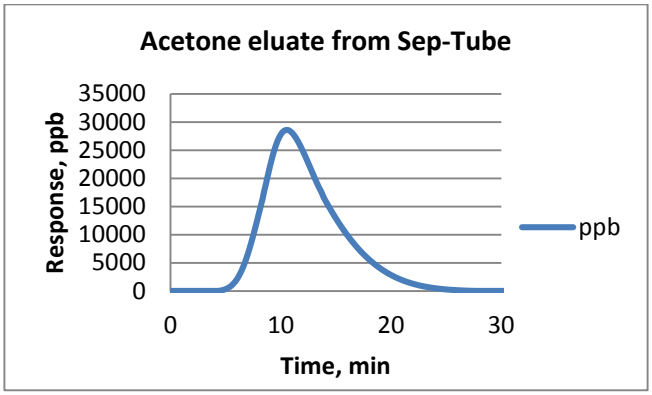
1. The monitor uses a lower-energy, 9.8eV PID lamp. This allows excluding from cross-contamination all the VOCs with ionization energy (IE) above 9.8eV.
2. RAE-Sep tubes eliminate most VOCs. Two major effects are present in them:
   - Gas absorption in the tube. This is usually a fast process, and it is reversible.
   - Gas reaction (chemical) in the tube. This is a slower process, and it is not reversible.

Note: Some VOCs can be eluted (removed) from the RAE-Sep Tube and cause false positive benzene readings.

In addition, if the instruments are insensitive to some gases (for example, their IE is above 9.8eV or if they require high correction factors), the products of their chemical reactions in RAE-Sep Tubes may become sensitive and may distort the benzene reading. A separate case is when gases don't absorb in the RAE-Sep Tube and are insensitive to the monitor equipped with a 9.8eV lamp (for example, lower hydrocarbons such as methane, ethane, etc.).

Example of Elution

When the instrument in Benzene mode was exposed to 400 ppm of acetone for 60 seconds, the reading didn't exceed 0.2 ppm. After 5 minutes running in air, the reading increased and reached almost 30 ppm.



Elution in Benzene mode with exposure to 400 ppm of acetone.

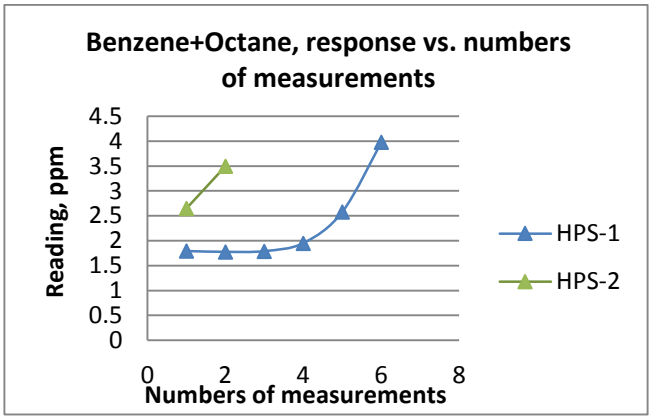
Acetone didn't convert in the RAE-Sep Tube within a short period of time (slow chemical reaction) and further eluted with the air stream.

Important: For the correct measurement and to avoid a false positive response, RAE-Sep Tubes should be used just one time.

Humidity Effect

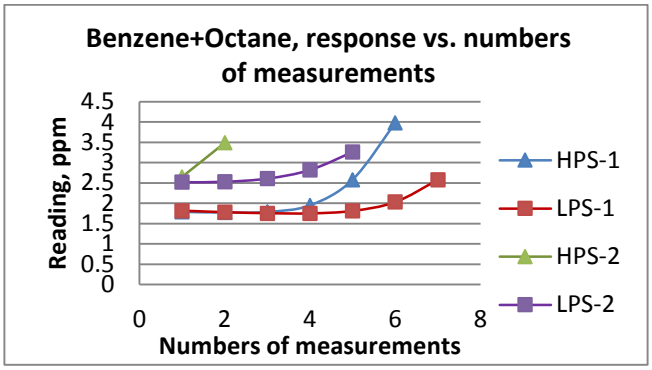
Humidity has no effect on the response to benzene. However, high humidity affects the capacitance of the tubes to remove interfering hydrocarbons, especially when they are in high concentrations.

The figure below shows the response of the instrument to the mix of benzene (2 ppm) and octane (180 ppm). HPS-2 is the case when the tube was opened and the instrument run with a high pump speed (HPS) for about 5 minutes in ambient air with relative humidity (RH) of 75 to 80% before a benzene measurement in Benzene mode was done. HPS-1 is the case when benzene measurements were done right after opening the tube.



Response of Benzene and Octane with different times of measurement after opening the tubes, HPS-1 and HPS-2. Each line represents a single tube, and each triangle represents a single measurement with that tube.

Tube capacitance can be extended significantly while using the instrument's low pump speed (LPS) instead of its high pump speed as default setting. Test conditions are the same as above.



Note: Previous results reinforce our strong recommendation to only open RAE-Sep Tubes right before performing a benzene-specific measurement. Other approaches could lead to false positive results.

Temperature Effects

Temperature variation affects RAE-Sep Tube performance. Decreasing temperature leads to the higher tube absorption, but slows down chemical transformation. As a result, the tube may not show a color change, but the tube fully or partially loses its capacitance. To avoid confusion, follow the recommendation of "One tube, one measurement." Note: Calibration should be performed at the same temperature as the measurement because time necessary for sampling changes with temperature.

Tube Capacitance

Tube capacitance in this case is defined as: MultiRAE Benzene with a RAE-Sep Tube exposed to the gases in the table for a limited time until the reading reached 0.5 ppm.

Concentration vs. Exposure Time

Gas	Gas concentration, ppm	Capacitance, minutes
Toluene	100	≥10
i-Butylene	100	≥10
i-Butylene	1000	5
Methane	25000	No response
n-Hexane	2400	10 sec
n-Octane	500	1*
n-Pentane	3500	7 sec
n-Propane	11000	No response

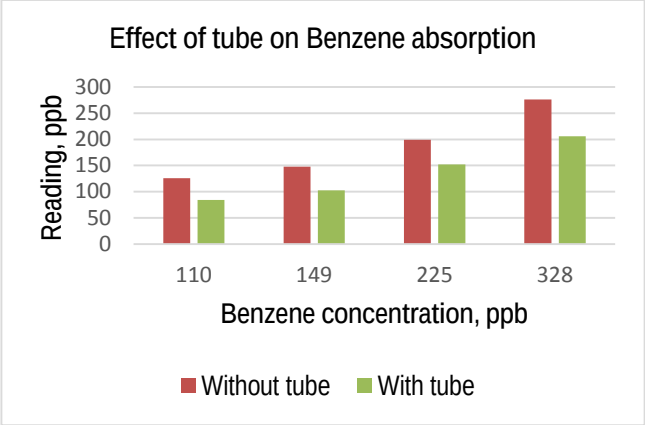
* Reading 1 ppm after 1 minute exposure

Potential Cross-Sensitivity

Gas Cross-sensitivity	Gas concentration, ppm	Benzene Response, ppm
Pentane	1700	0.1
Propane	5500	0
i-Butane	4500	0.5
i-Butylene	100	0.6
i-Butylene	1000	0.8
Methane	12500	0
Octane	250	0.3
Hexane	1200	0.6
Hexane	100	0
Butadiene 1,3	2.5	0.5
Toluene	50	1
Acetone	200	0.1

Benzene Absorption by RAE-Sep Tubes

There is a small effect of the benzene absorbtion by the RAE-Sep Tube that potentially could slightly decrease a benzene reading, but it doesn't exceed 50 to 60 ppb, which is below the instrument's resolution of 0.1 ppm (100ppb).



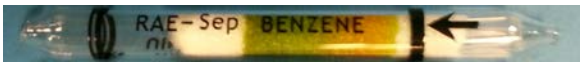
Examples of RAE-Sep Tubes' appearance after exposure to different VOCs and environment

Unused RAE-Sep tube. Note the uniform orange color of the fresh absorbant.

The following examples show various degrees of capacitance. Do not use opened tubes that look like these.

1. Freshly opened tube exposed to a mixture of benzene and octane. The exposure was over the tube's capacitance.

2. Open tube with instrument run for 5 minutes at 75 to 80% relative humidity and then exposed to a mixture of benzene and octane. The tube lost capacitance. The front part didn't absorb VOC.



3. Open tube with instrument run for 5 minutes at 75 to 80% relative humidity and then exposed to benzene and propane. The tube lost capacitance. The front part didn't absorb VOC, and the color is mostly brownish instead of green.

4. Freshly opened tube exposed to acetone. The tube's color almost didn't change, though tube capacitance suffered.

REFERENCES

1 California Code of Regulations, Section 5218: https://www.dir.ca.gov/title8/5218.html

2 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value: https://www.osha.gov/dts/chemicalsampling/data/CH_220100.html

3 MultiRAE User's Guide: http://www.raesystems.com/sites/default/files/content/resources/

4 MultiRAE Benzene Tube Cartridge Instructions: http://www.raesystems.com/sites/default/files/content/resources/MultiRAE%20Benzene%20Tube%20Cartridge%20QSG%20-%20A5_Page%20RevA2.pdf

5 MultiRAE Benzene Datasheet: http://www.raesystems.com/sites/default/files/content/resources/Datasheet_MultiRAE-%20Benzene_DS-1098-01.pdf