

## Benzene-Specific Measurements In Petroleum Hydrocarbons Using The RAE Systems UltraRAE 3000

### Introduction

Benzene is a known human carcinogen that is present in automotive gasoline and other fuels in concentrations typically 0.2 to 3%. Its regulated exposure limit is so low (proposed 8-hour day TWA of 0.5 ppm), that its concentration alone usually defines the toxicity of the fuel vapors as a whole. Thus, it is necessary to measure low concentrations of benzene (often  $\leq 1$  ppmv) in the presence of much higher concentrations (tens to hundreds of ppmv total) of the hundreds of aromatic and aliphatic compounds that make up gasoline.

### Specific Benzene Measurements

RAE-Sep™ benzene tubes scrub nearly all components out of gasoline vapors except benzene. This is accomplished through a proprietary absorption medium in the tubes. Further selectivity is afforded by using a 9.8 eV lamp, which responds strongly to aromatics but weakly to many hydrocarbons. Table 1 shows the response of the combined system to various challenge gases.

### Measurement Procedure

A separate tube is used for each measurement. The instrument is calibrated using a 5 ppm benzene standard with a RAE-Sep™ tube in place. When ready to measure, a tube is opened, it is inserted into the UltraRAE 3000, and the start button is pushed. A pump draws in the air sample at about 330 cc/min. and the unit automatically fixes the display and logs the value after 30 to 280 seconds, depending on the temperature.

### Tube Capacity and Matrix Effects

Benzene RAE-Sep™ tubes withstand 1000 ppm of toluene in dry air and 300 ppm at 50 to 80% RH (relative humidity). Tubes can be opened and left exposed to air for up to 4 hours without losing significant capacity.

Table 2 shows that humidity has no effect on the response to benzene. However, high humidity affects the capacity of the tube to remove interfering hydrocarbons.

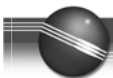
**Table 1.** Response to potential benzene interferences.

Compound	Concentration (ppmv)	Apparent Benzene Response
Toluene	400	0.1
p-Xylene	200	0.0
Ethylbenzene	200	0.0
Styrene	100	0.0
Nitrobenzene	100	0.0
Phenol	100 <sup>#</sup>	0.0
Chlorobenzene	20	2.5
Dichlorobenzene	50	0.1
Hydrogen Sulfide	150	0.0
Methane	25,000**	0.0
Propane	1,000	0.0
Isobutane	100	0.0
Isobutylene	500	0.0
n-Pentane	1,500	0.0
1,3-Butadiene	300	0.0
n-Hexane	100 <sup>#</sup>	0.0
Cyclohexane	10	0.4
n-Octane	300	0.1
$\beta$ -Pinene	50	0.0
Ethanol	50	0.0
Isopropanol	100	0.0
Acetone	100	0.0
Cyclohexanone	200	0.0
Tetrahydrofuran	100	0.0
Ethyl acetate	100	0.0
Acrylonitrile	100	0.0
Epichlorohydrin	100	0.0
Trichloroethylene	100	66
Perchloroethylene	50	38

\*Not necessarily the maximum allowable concentration.

\*\* No effect on tube capacity. Propane and higher hydrocarbons do affect capacity.

<sup>#</sup> Higher concentrations may cause a reduced benzene response.



Methane has no effect on tube capacity, but it reduces the response of the PID to benzene, when the methane concentration is above about 1% by volume. Propane and higher hydrocarbons consume part of the capacity of the tubes even if they give no response.

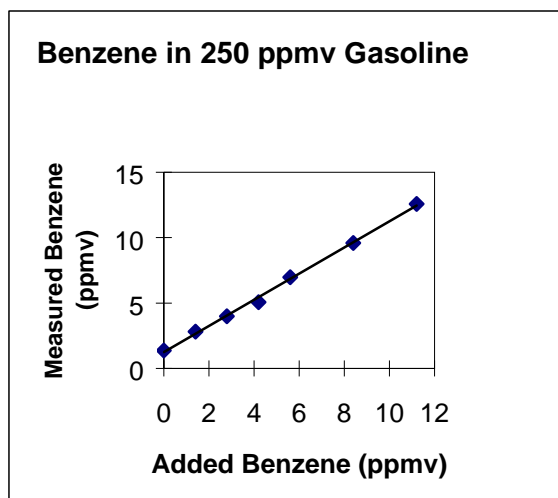
**Table 2.** Humidity effect on 5 ppm benzene standards.

Tube #	Relative Humidity	Reading (ppm)
1	Dry	5.0
2	Dry	4.9
3	100 %	5.1
4	100 %	4.8

### Sample Measurements

Figure 1 shows the linearity of the response when benzene is added to a sample of gasoline vapors. The correlation coefficient ( $r^2$ ) for the line is 0.998. This excellent linearity allows the use of a fast and simple single-point calibration.

**Figure 1.** Linearity of benzene response added to 250 ppmv of 92 octane gasoline. The sample contains 1.4 ppmv of benzene from the gasoline itself.



### Refinery Samples

Petroleum refineries have a variety of process streams that contain a broad range of benzene concentrations. Table 3 compares the results of the benzene-specific UltraRAE, obtained in one minute, with those of two-hour gas

chromatography (GC) runs in the laboratory. The good correlation between the two measurement systems shows the benefit of the time savings afforded by the UltraRAE 3000.

**Table 3.** Benzene in refinery samples.

Sample	Benzene by GC/FID (mole %)	Benzene by UltraRAE (mole %)
87 Octane Gasoline	0.86	0.63
Reformer Feed	1.2	1.0
Reformer Product	6.3	7.2
Benzene Light Ends	22	24

### Field Comparison

A study was conducted at four major oil refineries comparing the UltraRAE 3000 with three other benzene-specific portable measurement systems: the Photovac Snapshot handheld GC, the Dräger CMS, and laboratory GC. The results shown in Table 4 were obtained for the combined data from 18 different field samples and 24 standards, including BTEX mixtures:

**Table 4.** Field sample accuracies as percent of laboratory value  $\pm$  standard deviation.

Sample	UltraRAE	Snapshot	CMS
Standards	101 $\pm$ 16%	116 $\pm$ 23%	120 $\pm$ 52%
Field Samples	97 $\pm$ 29%	84 $\pm$ 21%	103 $\pm$ 92%

The Snapshot and UltraRAE 3000 gave similar results while the CMS tended to have greater variability. Complete results of the study are available on request.