

UNDERSTANDING AND OPERATING THE ppbRAE 3000



INTRODUCTION

The RAE Systems ppbRAE 3000 parts-per-billion (ppb) Volatile Organic Compound (VOC) Monitor is the most sensitive Photoionization Detector (PID) on the market. The ppbRAE 3000 is a broadband detector, and is able to measure a few ppb of VOCs in real time.

The ppbRAE 3000 is a best-of-breed monitor trusted by many of the world's leaders in CBRNE, HazMat Response, National Defense, Oil & Gas, Environmental, Industrial Safety and other hazardous environments.

The ppbRAE 3000 utilizes a third-generation PID and built-in correction factors for more than 200 compounds. RAE Systems' ppbRAE 3000 measures the presence of VOCs from 1 ppb to 10,000 ppm with a three-second response time.

Bluetooth data connectivity to a RAELink3 wireless router enables transmission up to 2 miles for data capture, incident monitoring, worker and responder safety awareness, and faster response. The ppbRAE 3000 includes a rugged housing, large display, and large keys that can be operated with three layers of gloves.



CALIBRATION

Zero Calibration

Ambient air contains a few tens to a few hundreds of ppb of organic vapors or other UV-ionizable compounds. These levels can usually be neglected with conventional ppm-level PIDs, but are very significant to the ppbRAE 3000, which works down to the ppb level. Therefore, an appropriate zeroing scheme and zero gas solution are extremely important for the ppbRAE 3000 to perform correctly in the low-ppb range.

Zeroing Scheme

In general, the purpose of zero calibration is to determine the signal for the background where the gas of interest exists. The zero signal consists of the electronic blank impulse plus the signal due to the matrix gas. Both the electronic blank impulse and the signal due to the matrix gas ideally should be cancelled. V1.20 and later firmware versions use zero gas to zero the unit, thereby canceling both the electronic blank and matrix gas signal. Therefore, the consistency among units at low concentrations is markedly improved.

An appropriate zero gas is required for zero calibration with V1.20 and higher version firmware. The lower the concentration of the VOC in the zero gas, the better the accuracy of the measurement in the low ppb range. Any zero gas for ppb zeroing preferably has less than 10 ppb total hydrocarbons and must have the same matrix as measurement. For example, if the ppbRAE 3000 is used to measure ppb-level VOC in air, the instrument must be zeroed with "ultra zero" air that consists of 21% oxygen and 79% nitrogen.



Zero Gas Sources

RAE Systems has developed the single-use VOC zeroing tube (RAE P/N 025-2000-010, as shown below) as the best and the most convenient provider of "ultra zero" air by purifying the ambient air running through it.

Possible ppbRAE 3000 zero gas sources are listed here in order of preference:

1. Single-use VOC zeroing tube (RAE Systems P/N 025-2000-010).



2. Large (>200 scf) laboratory ultra-zero air cylinder (<10 ppb VOC).



3. Disposable zero air cylinder (e.g., the 34-liter zero air cylinder, RAE Systems P/N 600-0024-000, as shown here).

4. Clean outdoor air.

5. Multiple-use organic vapor zeroing filter (RAE Systems P/N 490-0006-000, as shown here).



Before the development of the VOC zeroing tube, the multiple-use organic vapor zeroing filter was a recommended alternative zero gas solution for the ppbRAE 3000. The organic vapor zeroing filter has the following issues: (1) the container is plastic and may absorb and release organic vapors and plasticizers depending on the concentration difference and temperature; (2) the two ends of the filter are open to the environment, and contaminants can enter the filter; (3) it allows multiple use and hence makes it difficult to track the functionality status. As a result of the issues listed above, the repeatability and consistency among different charcoal filters is not guaranteed. For this reason, the organic vapor zeroing filters should be used only as a last resort when none of the other methods are available, recognizing that they may cause tens of ppb background to be subtracted.

The VOC zeroing tubes get rid of the conventional charcoal filter's shortcomings. First, the container is a glass tube and does not have the issues of plastic containers. Second, the two ends are airtight and glass-sealed. Third, it is designed for single use only.

Clean outdoor air is often a good source of zero air, but there is no simple way of ensuring <10 ppb VOC levels.

Pure nitrogen causes a zero shift from the air baseline and should not be used for zeroing the ppbRAE 3000, even though span gases at >1 ppm in nitrogen are still acceptable for span calibration.

Figure 1 summarizes typical results with the various zero sources. It can be seen that the VOC zeroing tube provides the best zero standard. Large or disposable cylinders must use a dedicated regulator to prevent cross-contamination if the regulator is also used for span gases. The VOC zeroing tube rules out this issue and offers more portability for field use.

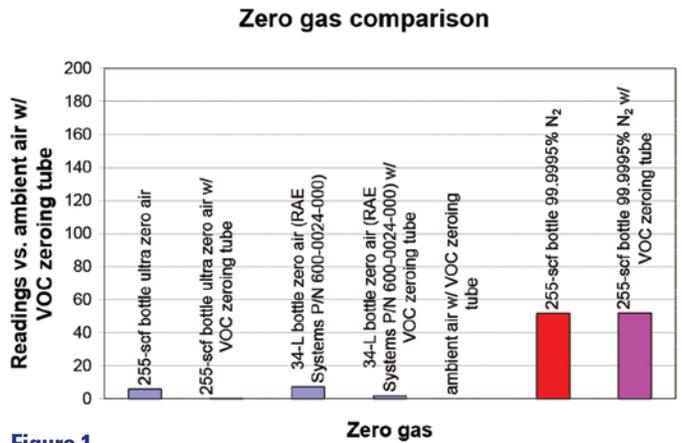


Figure 1.

The consistency between different VOC zeroing tubes is very good (among five VOC zeroing tubes, the consistency zeroing from ambient air is about ±1 ppb). The flow resistance of the VOC zeroing tube only causes 30 to 40mL/min (about 5%) sample flow rate reduction on the ppbRAE 3000. The VOC zeroing tube absorbs largely propane, propene and higher hydrocarbons, but not ethane, ethylene or methane.

Everything mentioned above relates to the absolute ppb VOC measurement. In many cases, only relative measurement is required. For example, closed areas, storage areas, clean rooms, and so on are the only subjects of the monitoring or measurement, not the areas outside. In these cases, calibration to zero may be performed and is even preferable, to the ambient air outside of the zone of the interest, but close to it.

Such a calibration has the advantage, since all other possible presented VOCs (not the VOCs of interest) reference to zero. Moreover, the temperature and the humidity in the calibration area may be about the same as in the measurement area, and they do not affect the real VOC measurement in the desired zone, especially for the low ppb levels of VOCs.

Span Calibration

A source of 10 ppm isobutylene is connected to the ppbRAE 3000 inlet for the span calibration. Preferably, the gas is supplied from a bottle of the compressed calibration gas with a T-type connection tubing (P/N M02-3008-000), to avoid pressure and flow rate differences. If the source of the calibration gas is a cylinder with compressed gas, be sure that the gas regulator (GR), attached to the cylinder provides at least a bit higher gas flow rate than the pump of the instrument, in order to avoid gas dilution. After both zero and span calibration, the ppbRAE 3000 is ready for use. It is easy to check if the ppbRAE 3000 reads correctly after calibration. In the presence of a known concentration of detectable gas (usually it is the calibration gas), the ppbRAE 3000 should display within a specified accuracy of $\pm 10\%$ of readings, within a reasonably short period of time after calibration.

SAMPLE MEASUREMENTS

For accurate measurements, follow the procedures outlined in the ppbRAE 3000 User's Guide available at http://www.raesystems.com/sites/default/files/content/resources/Manual_ppbRAE-3000_059-4021-000_RevC.pdf

Examples of the data in Figures 2 through 4 represent typical performance of ppbRAE 3000, and should not be treated as the specification.

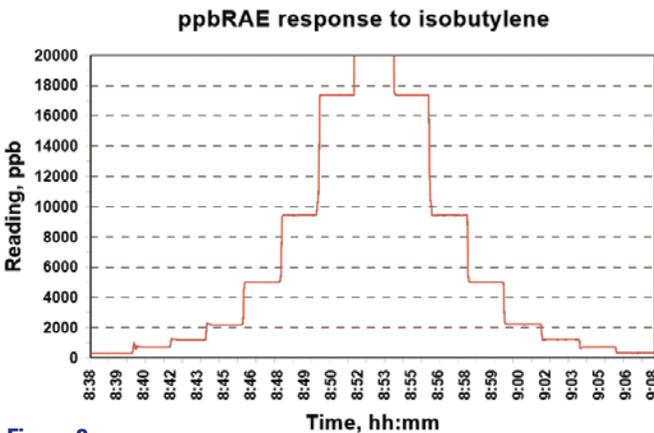


Figure 2.

Figure 2 shows the ppbRAE 3000's response to various concentrations of isobutylene in increasing and decreasing stair steps of each concentration for two minutes.

The response and recovery time of 90% change is less than 3 seconds. All measurements are accurate and repeatable within the specification, whether switching the gas from low to high concentration or vice versa.

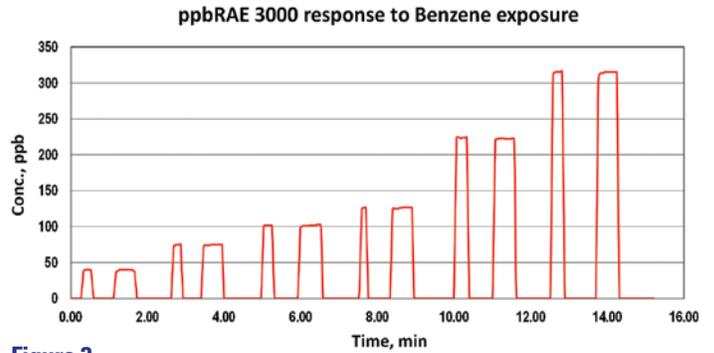


Figure 3.

Figure 3 shows the repeatable ppbRAE 3000 response to different low ppb levels of benzene concentrations. The gas exposure is 30 and 60 seconds in series. Various concentrations of Benzene were prepared in a 12-gallon jug by purging the selected gas amount to it and mixing with air. Response time to T90 and recovery time to T10 are consistently low and are in the range of 3 to 4 seconds.

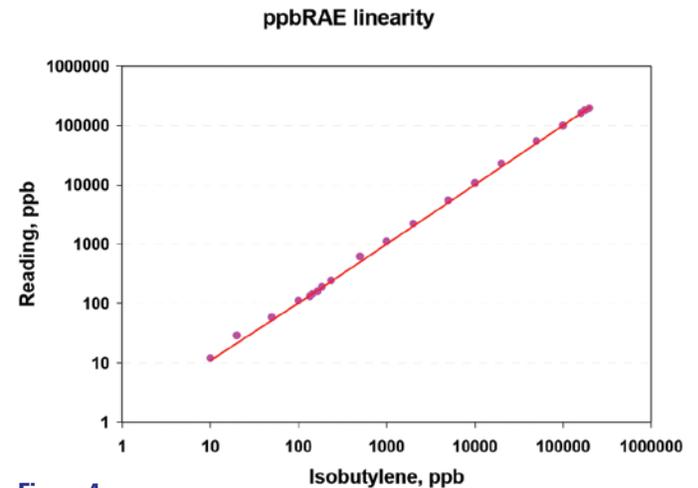


Figure 4.

Figure 4 shows that the ppbRAE 3000 gives a linear response in the range of 10 ppb to 200 ppm. Various concentrations of isobutylene were diluted from the same setup and cylinder. It should be noted that if different cylinders were used, differences in background impurities from cylinder to cylinder could cause a significant error in this kind of ppb-level measurement. Interconnecting tubing and Tedlar bags can also contribute significant error due to absorption

at low ppb levels or release of plasticizers or previously adsorbed compounds. The user needs to be extremely cautious to avoid contamination when experimenting at low ppb levels. An accurate and clean gas distribution and dilution system is recommended when performing this type of evaluation.

Semi-volatile or Reactive Chemicals

Heavy or reactive chemicals (e.g., hydrazine, phenol, methyl salicylate, dimethyl methylphosphonate, etc.) generally cause sample transferring loss due to the adsorption by the internal surface of the sample probe and the barrier (filters) in the sample probe. As a result, the response is slower or not visible for a period of time when the concentration of the chemical is low. Removing all the filters (including the mineral wool filter, the C-filter, and the stainless steel porous disk filter) is recommended for measuring heavy or reactive chemicals. In such cases, attention should also be paid to calibrate the unit in the same configuration with the filters removed. Reactive and polar gases may also be deposited on the surfaces of the PID lamp and the sensor, contaminate them, and distort the instrument reading. Measurement with a duty cycle may be appropriate to mitigate this effect. See RAE Systems Technical Note TN-165 for more information.