CALIFORNIA STATE SCIENCE FAIR
2012 PROJECT SUMMARY

Name(s)
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Project Number
S1816

Project Title
Using the Temperature Dependence of the Speed of Sound to Detect Volatile Organic Compounds in Air

Abstract

Objectives/Goals
The goal was to determine whether or not the temperature dependence of the speed of sound in air with harmful concentrations of volatile organic compounds (VOC's) would deviate enough from the predictions of the ideal gas law in order to make an effective and low-cost acoustic VOC sensor. Current VOC sensors based on photo-ionization are very sensitive but costly and therefore deployed mostly in industrial and laboratory environments. A low-cost sensor could be installed in every home and workplace to monitor indoor air quality.

Methods/Materials
The speed of sound was measured by measuring the resonant sound frequency in a closed tube. The tube was made with PVC, could be opened for cleaning, and had valves for insertion of gases and liquids. A speaker, microphone, and thermocouple were placed in the tube through holes sealed with epoxy. The speaker was driven by a precision sine wave generator. The microphone signal amplitude was detected using a laptop and the program Audacity. The resonant frequency (frequency of peak amplitude) was determined to 4 digits by averaging the frequency on the low and high frequency side of resonance at ~80% peak amplitude. The temperature was varied between -20^oC to +20^oC, by placing the resonant tube in the freezer section of a refrigerator and read out using the thermocouple to 0.1^oC. The gas mixture in the structure was varied by loading with clean air at -20^oC and then inserting small volumes of liquid VOC's: acetone and n-butane.

Results
The resonant frequency of the tube is linearly proportional to the velocity of sound and inversely proportional to the length of the tube. Allowing for the linear thermal expansion coefficient for PVC (published coefficient), the temperature dependence of the velocity of sound for clean air was nearly ideal with Sqrt(T) dependence. Air with VOC's showed additional temperature dependence that could be distinguished from ideal. The experimental accuracy and systematic uncertainties for this setup were estimated.

Conclusions/Discussion
Results suggest that with an improved experimental setup, it may be possible to make a VOC detector at the 1000 ppm level using the temperature dependence of the speed of sound. This range can be relevant to human safety: the ST (short term) OSHA PEL (Permissable Exposure Limit) for acetone is 1000 ppm.

Summary Statement
Experiments were conducted to measure the temperature dependence of the speed of sound in VOC-air mixtures and suggest that a low-cost acoustic sensor could be made with 1000 ppm sensitivity.

Help Received
Professor Harry Tom from University of California Riverside (UCR) loaned equipment, and supervised handling of VOC's and assembly of PVC structure.