Innovative Multi-Mode Vapor Thermal Desorption Devices

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ABSTRACT

Use of thermal desorption techniques is an established method for environmental and industrial hygiene studies of noxious vapors and their effects on health. Utility of the thermal desorption technique, however, has been hampered by rudimentary sampling equipment. With the improvements in recent years of electronic controls, Seacoast Science has designed, fabricated and lab-tested an innovative vapor sampler to assist in quantifying toxic industrial chemicals (TIC's) in the workplace. The samplers consist of multi-bank, multi-tube, individually addressable tube, sequential air-sampler modules. Air sampling campaigns are programmed into the modules using the on-board user interface, or uploaded from a computer via USB connection. The design objective was a readily transportable air sampler that allows the users to capture air samples using COTS thermal desorption tubes.

Keywords: thermal desorption, environmental monitoring, industrial hygiene, air-borne vapors, volatile organic compounds

1 INTRODUCTION

The US Dept. of Labor, Bureau of Labor Statistics reported 16,400 non-fatal occupational incidents of respiratory illness during 2016 [1]. Industrial hygienists and environmental scientists use various vapor-sampling technologies to measure both intensity and duration of exposures to potentially harmful vapors. Capturing air samples directly in chemically inert containers, such as Tedlar bags or Summa canisters, appears simple, but these air samplers are bulky, easily damaged in transport, and prone to contamination. An alternative sampling strategy involves thermal desorption [2] (TD) tubes utilizing engineered sorbents that capture and concentrate any noxious vapors from the air. TD tubes maintain chemical integrity of samples in a compact, robust form-factor. Utility of the thermal desorption technique, however, has been hampered by the rudimentary nature of currently available sampling equipment.

Our objective at Seacoast Science was to design and fabricate a readily transportable air sampler that is compatible with commercial-off-the-shelf (COTS) thermal desorption tubes. Seacoast has now demonstrated a four-tube module that automatically switches between TD tubes using flexible, preprogrammed, user-defined sequences (Figure 1). Further, up to eight sampler modules can be ganged to allow for extended sampling and / or replicate sampling of the air space. Air sampling campaigns are programmed into the modules using the on-board user interface or downloaded from a computer via USB connection.

Individual modules operate on 12 V DC power provided by a DC power supply. Alternatively, a module may be powered by a battery power pack. Use of a AA-battery pack can allow for air sampling using a single module for a work shift. Ganged modules are powered from a power supply connected to 110 VAC line power.

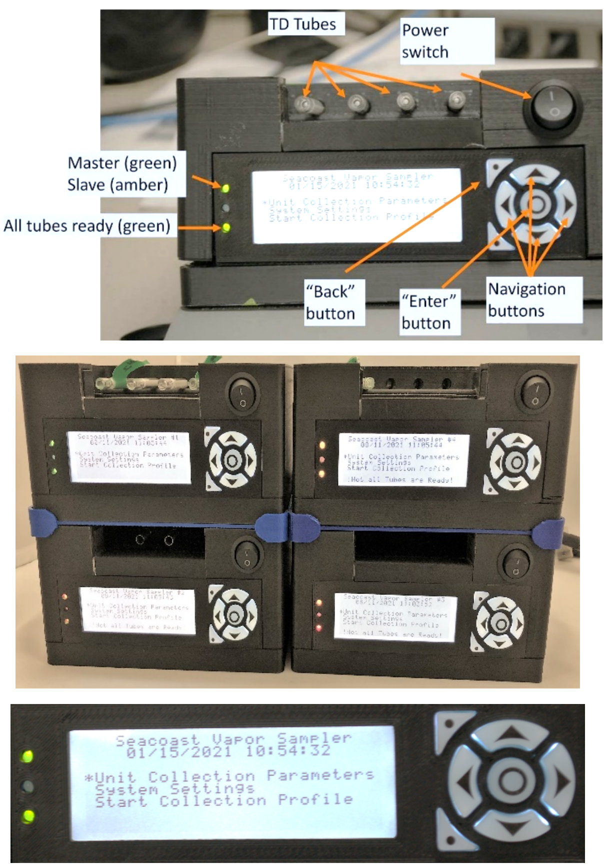

Figure 1. (top) Front panel of a SeaPort 4TD module, (middle) four modules in ganged configuration, and (bottom) close-up of front panel display.

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Design Objectives: Seacoast began with several specific design objectives, all of which were achieved in the final product:

- Accept COTS thermal desorption tubes (both stainless steel and glass tubes);
- Readily transportable, field-usable module controlling four TD tubes;
- Modules gangable for up to 32 independently addressable TD tubes;
- Option for replicate sampling (up to 8 replicates);
- Readily adjustable sampling flowrate & sampling volume;
- Include chemical sensor to initiate sampling;
- Tubes can be replaced without interrupting active sampling (hot swapping of TD tubes);
- Real time clock to allow scheduling of future operating times (schedule sampling events from seconds to months);

2 DESIGN FEATURES

In executing our design plan, Seacoast included many features to improve usability of the samplers. As mentioned above, each module operates with four TD tubes. Modules are gangable – up to 8 modules – to allow for any combination of extended sampling campaigns or replicate samples. Modules automatically recognize when they are in a ganged configuration.

The samplers accept both ¼” stainless steel and 6 mm glass tubes with any sorbent or configuration of multiple sorbents. Sampling rates range from 10 to 500 mL / min; sampling volumes range from mL to multi-liters. Each tube in a module is independently programmable to allow for different start triggers, different start times, different sampling rates, and different sampling volumes. Sampling may be started in one of four ways:

- Immediately upon user’s button press, or
- At user-specified date and time (MM:DD:HH:MM:SS), or
- When chemical vapor is detected (user-adjustable trigger threshold), or
- When preceding tube has completed sampling.

Tube independence is maintained in the ganged configuration, and tubes in later modules can be programmed to follow tubes in the preceding module to maintain sequential collections.

An innovative feature is the photoionization chemical vapor detector to automatically initiate air sampling if a vapor is detected in the air. The trigger threshold is user-adjustable through the on-board navigation menu. The detection limit of this detector is in the ppb range.

Flexibility in sampling rates and volumes is possible because of the electronic flowrate sensor (Figure 2). Compactness is made possible through use of miniature valves (Figure 3) to allow the individualized operation of each tube. Optical detectors track tube replacement, allowing for removal and replacement of tubes that have been exposed without interrupting on-going sampling schedules. This feature allows a user to sample indefinitely if the situation requires it. LED indicators display exposure status of individual tubes, including fault indication if any tube is missing before a sampling campaign begins (Figure 4). A warning also is displayed on the front panel when a tube error is detected (Figure 5).

Figure 2. Honeywell electronic air flow sensor.

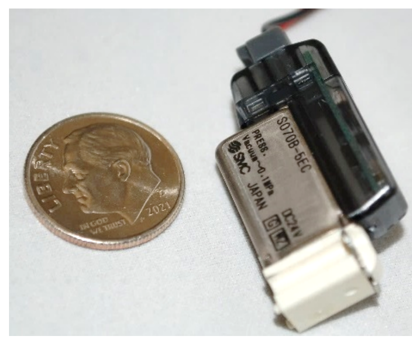


Figure 3. SMC miniature valve.

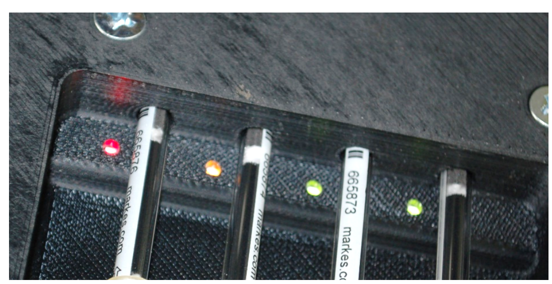


Figure 4. Status lights for individual tubes: steady red = complete; blinking amber = in use; steady green = ready.

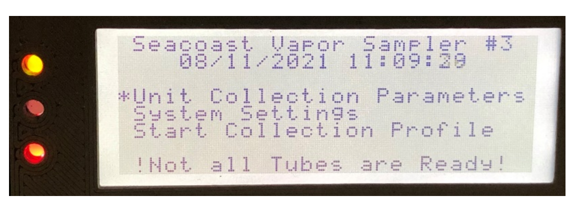


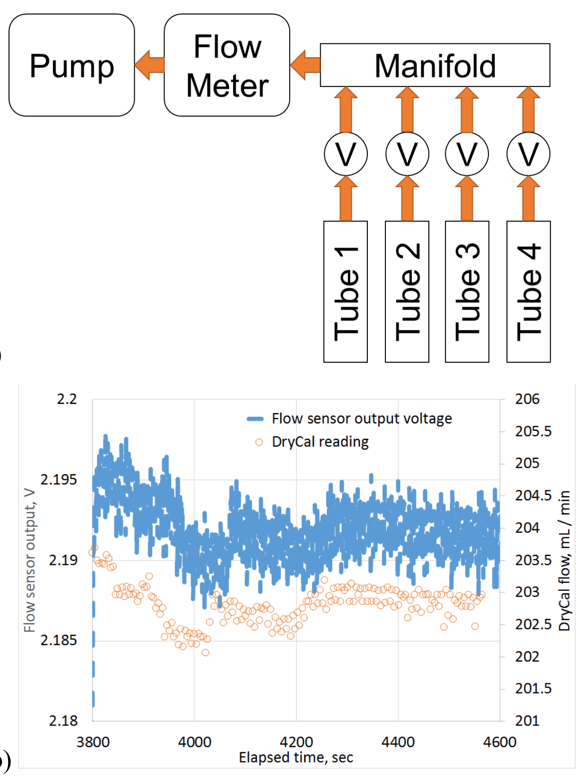
Figure 5. Module front panel with red LED and warning text of a tube error.

Each module includes a real-time clock with battery back-up. The time can be adjusted using the navigation buttons on the front panel. This allows the user to set system time to the local time.

Each module has an illuminated touch pad to navigate set-up menus. Each module creates an electronic record of sampling events; this report can be access either through USB connection or via WiFi. Temperature and humidity from an on-board detector are also stored in the electronic record.

3 SYSTEM PERFORMANCE

Modules were tested for flow reproducibility using a calibrated external flow meter (Bios Dry Cal). A 4-wire brushless-motor pump (KNF) is used in the modules to pump air through the tubes, using a manifold and valves to select the active tube (Figure 6). A feedback control circuit measures the reading from the flow meter and adjusts control voltage to the pump multiple times per second to ensure steady, consistent air sampling rates. Figure 6b shows test data at constant flowrate setting. Air flow measurements through an active TD tube (Tenax packing in glass tube) deviates less than 1% from setpoint during the run. The actual flow rate is integrated over time to calculate and report the true volume collected.

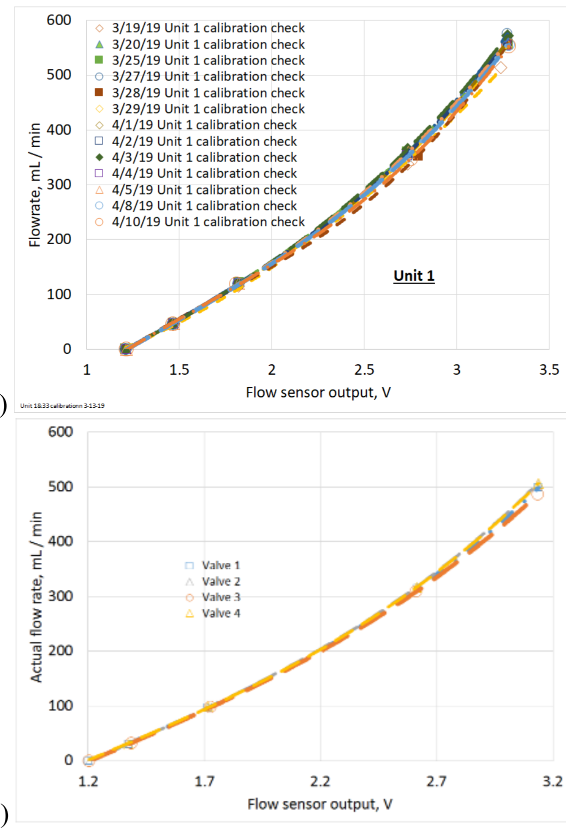


(a)

(b)

Figure 6. (a) Module manifold and (b) plot of the internal electronic flow meter readings and independent flow meter with the flow set to 200 ml/m.

Figure 7 shows data from these tests and indicates that the flow is consistent on a day-to-day basis. Tests were run to measure air flow through different thermal desorption tubes at each valve location in the prototypes (Figure 7b) and indicate that the flow is consistent among TD tubes; thus, the vapor collection prototype proved internally consistent.



(a)

(b)

Figure 7. (a) Flow repeatability testing showing good day-to-day consistency using a single TD tube inserted into the same location, and (b) consistency using four individual Tenax glass TD tubes in each position.

4 CONCLUSION

Seacoast Science has fabricated and demonstrated an innovative instrument that allows the user to meter air samples through COTS thermal desorption tubes. This instrument incorporates electronic flow monitoring for better accuracy in sample collection as well as a sensitive chemical detector to initiate air sampling when needed. This instrumentation fills a critical need in identifying and quantifying noxious vapors in the environment.

5 ACKNOWLEDGEMENT

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0109. The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation.

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[2] US Environmental Protection Agency, Method 624: - Purgeables, www.epa.gov, promulgated 1984, 28 pp.