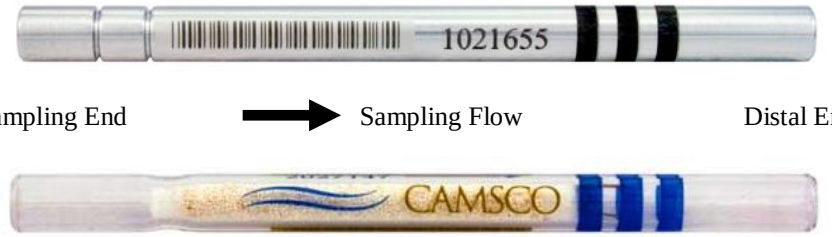
This document provides a general guideline to air sampling practice using CAMSCO's thermal desorption (TD) tubes:

1. Sampling direction
2. Tube storage before and after sampling
3. Comparing active and passive sampling
4. Active sampling and breakthrough volume
5. Passive sampling and diffusive uptake rates
6. Analysis and quantification

1. Sampling direction

- The direction of the text/number readout is the direction of sampling air flow:



- As shown in the picture above, the sampling end is where the air sample ingress; and the distal end either stays sealed for passive sampling, or gets connected to a vacuum pump for active sampling.
- For CAMSCO's steel tubes, the sampling end is the end with double "corsets".
- For CAMSCO's fritted glass tubes, the sampling end is the end with the frit installed.
- For multi-bed tube, the weaker sorbent should be packed closer to the sampling end.
- The desorption flow is the reverse of the sampling flow; please follow the instruction of your instrument when you load the tubes onto a thermal desorber to be analyzed.

2. Tube storage before and after sampling

- Tubes need to be thoroughly conditioned before sampling. Please refer to *CAMSCO Conditioning Instruction* for details.
- Tubes need to be sealed by compression caps before and after field sampling.
  - Hand-tighten the compression caps first, then use wrench to further tighten a quarter of a turn.
  - Too much tightening may destroy the ferrule inside the cap, and insufficient tightening may lead to contaminations.

- Storage time is highly dependent on the sorbent material as well as the storage conditions:
  - Do not store your tubes in freezer (below 0°C).
  - Do not put your tubes in refrigerator unless it is a multi-bed tube loaded with samples. Single-bed tubes (clean or loaded) and clean multi-bed tubes don't need refrigeration, but in some cases refrigeration helps to slow down the migration of adsorbed samples from weaker to stronger sorbents.

- Do not de-cap tubes right after taking them out of a refrigerator, or cold environment. It is recommended that tubes be kept sealed until they reach ambient temperature to avoid water condensation, which could bring problems to GC/MS.
- Some polymeric sorbents, such as Chromosorb and Porapak, may automatically generate aromatic background over time. It is thus recommended to use conditioned tubes as soon as possible after conditioning. Carbon-based sorbents, however, can be stored for longer period of time (usually weeks).
- Tubes that have been stored for months normally need re-conditioning.
- A blank tube (conditioned but not brought to the field) and a control tube (brought to the field but not sampled) may be tested for each batch of sample to verify cleanliness.

- Analytical caps and micro caps cannot be used for long-term storage.

3. Comparing active and passive sampling

- Active sampling, or pumped sampling, depends on a vacuum pump to draw a certain volume of air sample through the tube.
- Passive sampling, or diffusive sampling, depends on diffusion over a period of time to collect sample.
- A comparison can be found in the table below:

	Active Sampling	Passive Sampling
Need pump & electricity? Generate noise during sampling?	Yes	No
Need passive sampling caps?	No	Yes
Compatible tube material	Steel or glass tubes	Steel tubes only
Compatible tube size	Any size	3.5 inch x ¼ inch O.D.
Compatible number of sorbent bed in each tube	Single or multi-bed	Single-bed only
Compatible ambient VOC concentration range	No limit	2 $\mu g/m^3$ to 10 mg/m^3
Compatible with trace analysis (sub ppb to ppt)?	Yes	Not always
Glass wool plug before the first sorbent?	Yes or No	No
Sample collection	Liters (volume)	Hours/Days/weeks (time)
Results represent the air quality at a certain time point?	Yes	No
Results represent the air quality averaged over days/weeks?	No	Yes
Results affected by ambient wind and temperature?	No	Yes
Results affected by back-diffusion or inner-tube migration?	No	Yes
Possible breakthrough?	Yes	No
Sensitive to the pressure drop profile?	Yes	No
Utilization of the sorbent bed	Whole	Only the very front portion
Data accuracy	Quantitative	Semi-quantitative
What parameter is needed to calculate ambient VOC concentrations?	Air Sample Volume	Diffusive uptake rates

4. Active sampling and breakthrough volume

- Vacuum pumps are readily available from a variety of suppliers, and CAMSCO tubes will work with any high quality pump.
    - Battery-powered pumps are portable for personal monitoring, and AC-powered pumps tend to be more reliable for long-term sampling.
    - Modern pumps offer more and more user-friendly features, such as multi-channel parallel sampling, programing, miniature size, low-noise operation, wireless connection and remote control. However, reliability and accuracy remain the most important factors on the checklist. The quality of a vacuum pump directly affects the repeatability of the data, and the longevity of the tube.
- Sampling flow rate is normally 30 ~ 200 ml/min, and the most popular numbers seem to be either 50 ml/min or 60 ml/min for ease of calculation.
    - Most pumps are less accurate/linear at rates below 30 ml/min, and very few pumps can reliably work at ~10 ml/min.
    - At more than 200 ml/min, the pump may put too much pressure on the sorbent bed, and shorten the life of the tube by either creating short path or crashing friable sorbents into smaller particles. It is generally recommended to sample at a moderate rate pump speed for a longer period of time.

  The volume of air sample to be collected is determined by several factors such as tube type, concentration of target analyte, and humidity.
    - For example, the Air Toxics Tube, also known as the EPA TO-17 Tube Style 2, is suitable for compounds ranging in volatility from C3 to C12 for air volumes of 2 L at relative humidities below 65% and temperatures below 30°C. At humidities above 65% and ambient temperatures above 30°C, air volumes should be reduced to 0.5 L. Air volumes may be extended to 5 L or more for species ranging in volatility from C4.

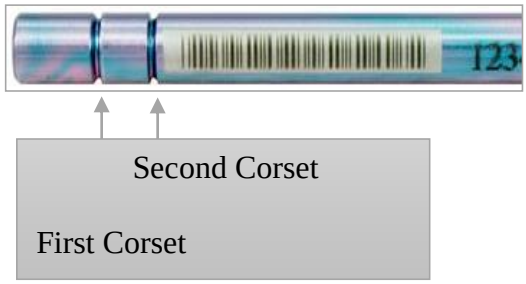
Breakthrough is a major concern for active sampling.

- While it is desirable to increase the sampling volume in order to achieve better reporting limits, oversampling may saturate the sorbent tube and lead to breakthrough.
- Sample volume should not exceed Safety Sampling Volume (SSV), which is defined as 2/3 of the breakthrough volume.
- For more information regarding SSV and break through volume, please refer to the ***CAMSCO Breakthrough Volume Poster*** for Tenax TA, or the Appendix 1 in EPA Method TO-17.
- As the tubes age, the SSV decreases as a result of sorbent degradation. One of the easiest tests of tube life is a "backup tube" experiment, in which the old tube being tested is connected in series to a new/clean tube, and then to the vacuum pump (sees illustration above). After routing sampling, both tubes can be analyzed; and a significant amount (>5%) of analytes on the second tube indicates the breakthrough of the first tube. While the use of "backup tube" will increase media costs, it usually have little effect on sample costs. It will, however, provide definitive support on data integrity.

5. Passive Sampling and diffusive uptake rates

- **The "industry standard" passive sampling tube** is specified as 3.5 inch x 1/4 inch O.D. stainless steel tube or inert-coated stainless steel tube. CAMSCO's tubes are made strictly in compliance with the industry standard.
    - The passive sampling tube has a cross sectional area of 0.191 cm^2 and a sorbent retaining mesh disk positioned 14.3 mm from the sampling end of the tube. This typically gives a diffusive path length (air gap) of 1.5 cm.

- To keep the 1.5 cm air gap consistent among passive sampling tubes, there's no glass wool plug in front of the sorbent bed at the sampling end. So we highly recommend clients to note "for passive sampling" on their purchase order.
- There are two "corsets" at the sampling end of the tube (see illustration to the right). The first corset sits an O-ring inside the passive sampling cap, and the second corset sits a pen clip for the convenience of personal air monitoring.
- However, the more important role of the second corset is to hold the mesh disk inside the tube, and define the 1.5 cm air gap required for consistent passive sampling.



- Some manufacturers make tubes with only one corset (the second corset). CAMSCO tubes come with double corsets followed by a barcode and a serial number, whose length combine to indicate the instrumental heating zone of PerkinElmer ATD thermal desorbers.

- **<u>Diffusive Uptake Rates</u>** are critical for calculations after passive sampling. Unfortunately only a limited numbers of laboratories have the sophisticated equipment/capabilities to determine such rates.
  - It is worth noting that the three presumptions used for passive sampling are:
    - ambient concentration of the analyte at the sampling end of the tube;
    - zero concentration of the analyte at the surface of the sorbent;
    - a linear concentration gradient between the two.
  - Passive sampling can be conducted for as long as the 3 assumptions apply, thus it is desirable to:
    - choose CAMSCO's high quality "industry standard" tube, whose geometry is strictly defined
    - choose a sorbent that is strong enough for the analytes, so that back-diffusion is negligible
    - use a passive sampling cap to maintain a relatively stable gradient and minimize turbulence
  - When these presumptions apply, Fick's 1st Law of Diffusion applies and analytes will migrate to the surface of the sorbent at a rate that is dependent on:
    - the geometry of the sampling tube, such as the length of the air gap and the cross-sectional area at the sampling end
    - the time of exposure
    - the diffusion coefficient of the analyte through air
    - the ambient concentration of the components
  - For example, Diffusive Uptake Rates for BTEX on Carbograph™ 5TD / Carbopack™ X:
    - Benzene: 1.99 ng/ppm•min
    - Toluene: 1.98 ng/ppm•min
    - Ethyl Benzene: 2.3 ng/ppm•min
    - P-Xylene: 2.00 ng/ppm•min
    - O-Xylene: 2.10 ng/ppm•min

Passive Sampling Accessories include passive sampling cap, pen clip, and protective tube shelter.

- A passive sampling cap prevents bugs and bees, and raindrops from entering the sampling cap.
- Another function of the passive sampling cap is to minimize the effect of turbulence.
- CAMSCO's tube shelter protects the tube from direct sunlight and rainfall, and comes standard with fenceline mounting fixture as well as dual tube holders, whose position has been optimized for industry standard tubes.

- **Installation of passive sampling tubes**:
  - For personal monitoring, tubes should be worn in the carrying person's breath zone, which means chest/collar level on the cloth, or directly mounted on a helmet.
  - For outdoor monitoring, such as fenceline monitoring, tubes should be hung at about 5 feet above ground, which is the nose height of a normal person.
  - In either case, the tube should be secured with the sampling end pointing downwards. This prevents rain and particles from directly falling into the tube.
  - Passive sampling starts when the compression cap on the sampling end is taken off; and ends when the compression cap is put back on. Field personnel should record the starting and ending time, as well as other desirable parameters such as temperature and humidity.

6. Analysis and quantification

- Tube analysis can be done by laboratories equipped with compatible TD-GC/MS systems.
- It is recommended that tubes be sent for analysis as soon as field sampling is complete.
- Quantification can be done with the following items:
  - Chemical standards (available from many standard companies)
  - Calibration Solution Loading Rig (available from CAMSCO)
  - Diffusive uptake rates (for passive sampling only, available from various sources of publications)
- If an uptake rate is not available for a given analyte there are several options:

1. Calculate an ideal value from Fick's equation and diffusion coefficients published in the literature
2. Determine the uptake rate experimentally using one of the following internationally recognized protocols:
   - Protocol for assessing the performance of a diffusive sampler; UK Health & Safety Executive, Methods for the Determination of Hazardous Substances No. 27.
   - CEN Pr EN 838: Workplace atmospheres - requirements and test methods for diffusive samplers for the determination of gases and vapours; CEN/TC 137/N55 (1991)

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