HAP CAPTURE AND CONTROL

Industrial Hygiene Procedures to Prevent Worker and Community Exposures to Hazardous Air Pollutants from Industrial Processes

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Methodologies, Control Technologies and Performance Testing

Introduction

Exposure to hazardous air pollutants in industrial processes such as textiles, manufacturing, printing, fuel processing and surface coating operations not only poses acute and chronic illness risks to workers but can also impact surrounding communities with similar risks and generate odor complaints. Fugitive emissions from these types of processes are controlled with capture systems that sequester the dangerous HAPs and deliver them to either destruction (thermal oxidizers), removal (scrubbers) or recovery (carbon adsorption/absorption) controls. The performance of capture/control systems require testing to evaluate their effectiveness.

This presentation will review the various types of HAP controls, with an emphasis on Volatile Organic Compounds (VOCs) – VHAPs and applicable environmental regulations. The procedures used to evaluate performance will identified and the science behind the sampling will be examined.

Capture and Control Systems and Performance

This presentation will review the various types of VHAP controls and applicable environmental regulations. The procedures used to evaluate performance will identified and the science behind the sampling will be examined.

1. **Capture System Techniques and Technologies –**The capture system is key to eliminating the fugitive emissions from the breathing zones of workers and surrounding communities.
2. **Control System Techniques and Technologies –**. Removal of VHAPS from the captured gas stream must be sufficient to reduce airborne concentrations to safe levels before process gases are exhausted to atmosphere.
3. **Performance Testing of Capture Systems –** USEPA has defined test procedures to evaluate the effectiveness of capture systems. These methods must be followed prior to evaluating control systems to ensure the source of VHAPS are properly controlled, and that loadings to the control system are representative of real-time operations.
4. **Performance Testing of Control Systems –** The methodologies for determining emission rates and destruction/removal efficiencies of VHAPS control systems are complex and require skilled and careful measurements.

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WHAT ARE HAPs

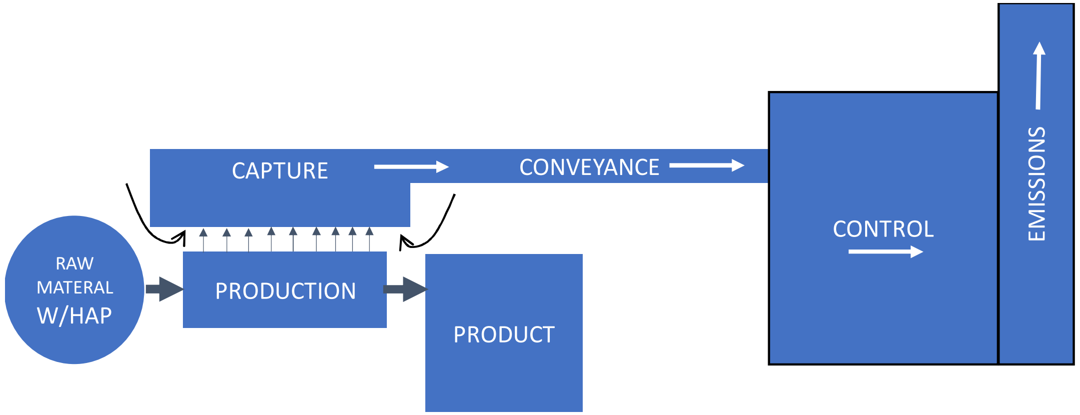
HAPs (Also termed Toxic Air Pollutants/Air Toxics)

- Primarily identified under the Clean Air Act (currently 187 compounds)
- Not necessarily the only HAPs Requiring Control
- Include volatile organic compounds (gases), Semi-Volatile Organics (gases, aerosols and particulate) and inorganics and metals (particulate)
- Primary exposure route – Inhalation, ingestion, absorption
- Capture/Control Systems engineered for physical characteristics (gases, aerosols, particulates)

INDUSTRY TYPES

- Textile Coating (VOCs, PM, Metals)
- Pharmaceutical (EtO)
- Automotive (Methanol, Paints)
- Manufacturing (PFAS)
- Chemical (acid gases, VOCs)
- O&G Midstream (Bulk Gasoline Terminals and marine loading operations)

WHAT IS CAPTURE/CONTROL



Basic Components Include –

- Process (HAPs Generator).
- Capture System - HAPs are captured through effective local exhaust ventilation or general ventilation controls.
- Conveyance - Captured HAPs are ducted from Process to Emissions Control.
- Control - HAPs are either recovered or destroyed.
- Emissions – Exhaust gases from the Control are Expelled to Atmosphere.

METRICS OF CAPTURE/CONTROL

- Capture Efficiency - percent of emissions generated from process that are conveyed to the control system.
- Control Efficiency – percent of captured emissions that are recovered or destroyed before exhausting to atmosphere
- Capture efficiency is evaluated to quantify worker exposure risks.
- Control Efficiency is evaluated to quantify community exposure risks.
- Both Capture and Control need to be quantified to ensure safe levels of exposure

CAPTURE SYSTEMS – Operational and Design Considerations

- Raw Material – what are the HAPs that are part of ingredients or by-products. Physical characteristics (gas, aerosols, particulate, etc)
- Production/Operations – application rates, heat, web widths, web lengths, other process metrics (gasoline loading for example).
- HAPs introduced through production (depositing substrates on a web matrix)
- Volatilization occurs from evaporation, evaporative heating
- grinding/crushing or other process
- Different processes will require different capture systems.

CAPTURE SYSTEM TYPES

- Local Exhaust Ventilation
- Total Enclosures - Permanent Total Enclosures (PTEs) or Temporary Total Enclosures
- Non-Total or Partial Enclosures (PEs)
- PTE and TTE Criteria Defined in USEPA Method 204 (40CFR 51, Appendix M)
- If PTE or TTE meet M204 criteria Capture Efficiency is assumed to be 100% (no need for measurements)

CAPTURE SYSTEMS – M204 Criteria

1. Any natural draft opening (NDO) shall be at least four equivalent opening diameters from each VOC emitting point;
2. The total area of all NDOs shall not exceed 5 percent of the surface area of the enclosure four walls, floor, and ceiling;
3. The average face velocity (FV) of air through all NDOs shall be at least 3,600 m/hr (200 ft/min);
4. All access doors and windows whose areas are not included in the calculation in item No. 2 shall be closed during routine operation of the process; and
5. All VOC emissions must be captured and contained for discharge through a control device.

CAPTURE SYSTEMS – Partial Enclosures

- If enclosure does not meet M204 criteria it is a PE
- Capture Efficiency is determined by measurement
- Typically requires construction of a Temporary Total Enclosure (TTE)
- USEPA Methods 204A, B, C, D, E and F (or some combination)
- Includes three points of measurement –

1. Capture
2. Fugitive
3. Background

CAPTURE EFFICIENCY MEASUREMENTS

- Three Points Measured – Captured, Fugitive and Background
- Total Hydrocarbons (THC) measured via USEPA Method 25A (by Flame Ionization Detector (FID))
- Duct flows are measured via USEPA Methods 1 and 2 (Pitot Tube for Velocity Head and Thermocouple for Gas temperature)
- Mass exhaust rates of captured and fugitive emissions are determined
- Capture Efficiency (CE) = $THC_C/(THC_C+THC_F)$

HAPs CONTROL TECHNIQUES

- Destruction – (creates emissions)
  - Regenerative Thermal Oxidation (RTO)
  - Catalytic Thermal Oxidation (CTO)
  - Flares (open/candle and enclosed)

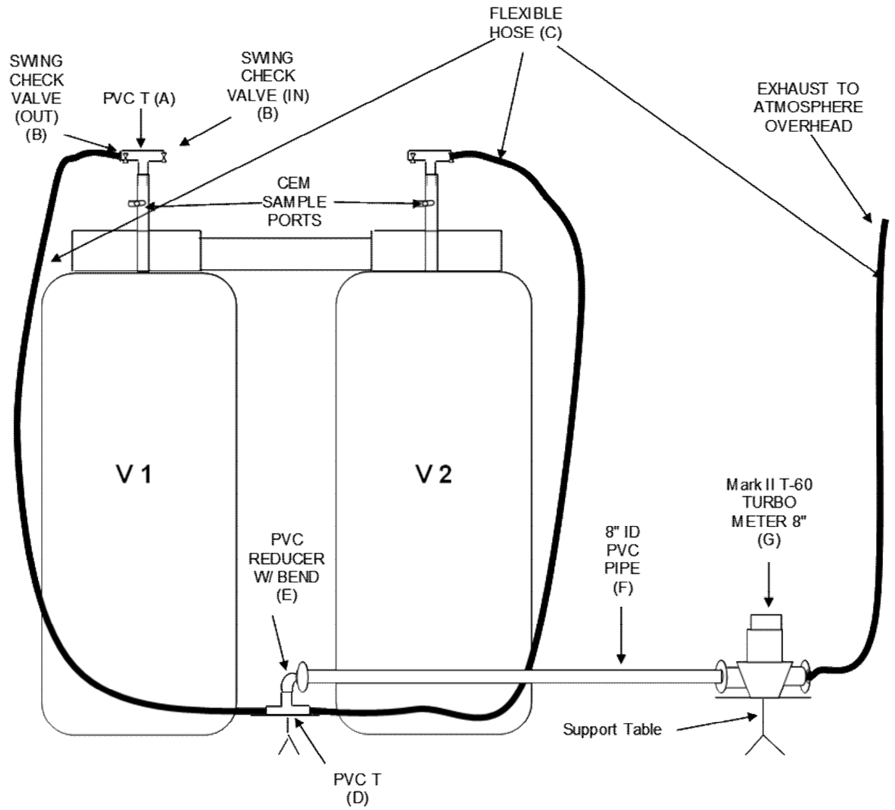
- Removal – (creates a solid or liquid waste stream)
  - Caustic Scrubbing
  - Wet Scrubbing
  - Dry Scrubbing

- Recovery – (creates a solid waste stream)
  - Carbon Adsorption/Absorption
  - Typically sends lost product back to production

HAPs CONTROL TECHNIQUES – Thermal Destruction

- Captured VOCs are thermally broken down into CO2 and H2O in high temperature incinerators.
- Regenerative Thermal Oxidizers (RTOs) use a series of combustion chambers with catalyst. Chambers are switched at fixed intervals during operation to allow periodic regeneration of catalyst with continuous operation.
- Catalytic oxidation typically performs for fixed period of time and then engine (operation) needs to be shut down for catalyst change out.
- Combustion Flares and Candle Flares (usually applied to methane destruction)
- Super-Critical Water Oxidation (SCWO) – promising for destruction of difficult chemicals like PFAS, PCBs, dioxanes/furans.

HAPs CONTROL TECHNOLGOIES – Recovery



- Recovers gasoline vapors from bulk truck or marine loading operations.
- 40 CFR Part 63 Subpart XX and YY
- Uses dual carbon adsorption/absorption to capture vapors.
- One carbon bed will recover vapors while the other carbon bed regenerates.
- Captured gasoline vapors are reconstituted by “washing” carbon with pressurized methane gas.
- Captured vapors are recirculated into the gasoline supply.

HAPs CONTROL PERFORMANCE

- Inlet and outlet are tested simultaneously.
- Total Hydrocarbons (THC) is measured in lb/hr via USEPA Methods 25A.
- Flow and moisture are measured via USEPA Methods 1 through 4.
- Mass loading on inlet and emissions on outlet are calculated from the following equation:

$M_{THC} = C_{THC} \text{ x } F \text{ x } 1\text{lb-mole}/386.8\text{ft}^3 \text{ x } 60 \text{ min/hr x } 10^{-6}$

CTHC = Concentration of THC measured in ppmvd

F = Stack or duct flow rate measured in dscfm.

HAPs CONTROL PERFORMANCE

- Destruction/Removal efficiency is calculated as the fraction of the mass of VOC destroyed or removed over the maas of VOC loaded.

$$DRE = (M_{THCIN} - M_{THCOUT})/M_{THCIN}$$

USEPA METHOD 1

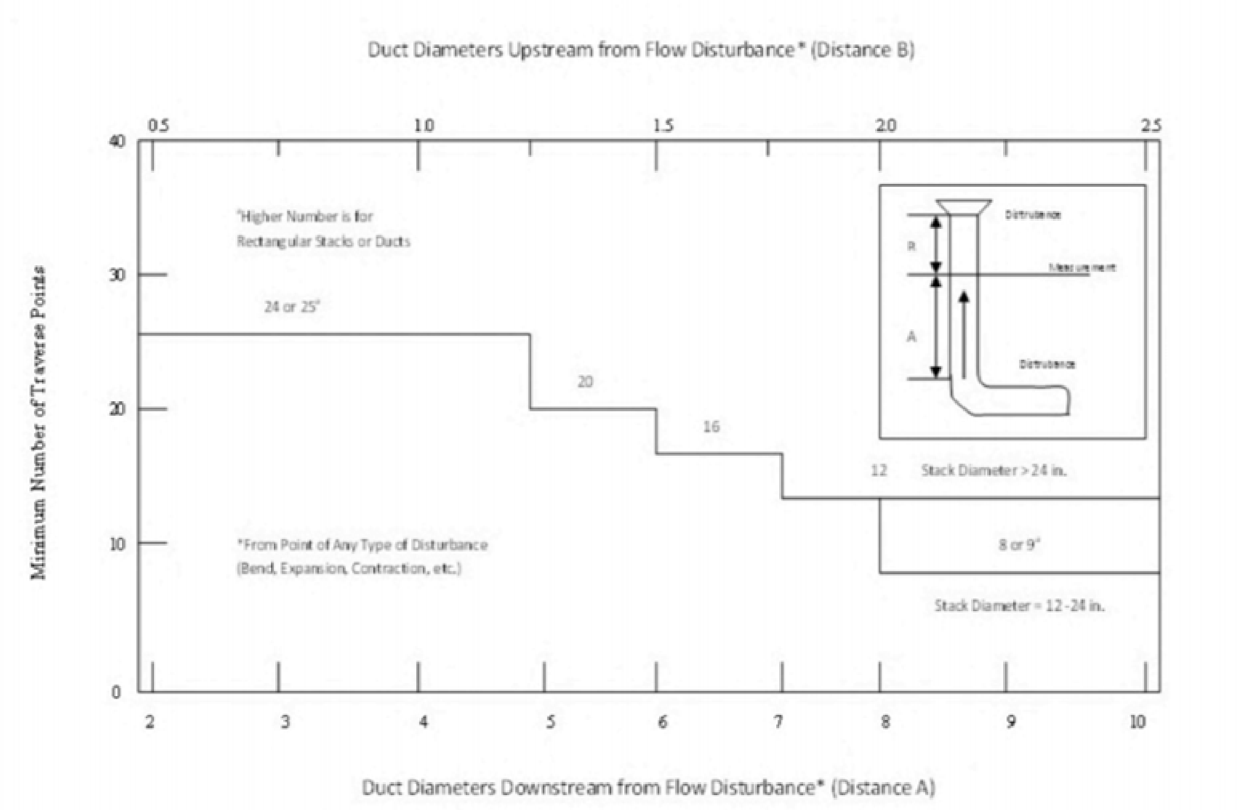


Figure 1-3. Minimum number of traverse points for an isokinetic sampling

STACK GAS VELOCITY

- Straight Stacks/Ducts with test ports - 2 diameters downstream and 8 diameters upstream (ideal) from flow disturbance (0.5 and 2.0 minimum) – Laminar Flow
- Minimum of two test ports required for perpendicular traverse
- Stack – 12-inch minimum diameter (preferable) alternate procedures for smaller diameters.
- Minimum of 8 traverse points (4 points per port) – Rectangular stacks minimum 9-point grid. Determined from number of diameters before and after test ports.
- Stack is divided into equal areas and traverse points are located at the center of each area.
- Absence of cyclonic flow (yaw angles <20^{o}) – directional flow sensing probes.
- Velocity is an exponential function (Sq.Rt) of dP.

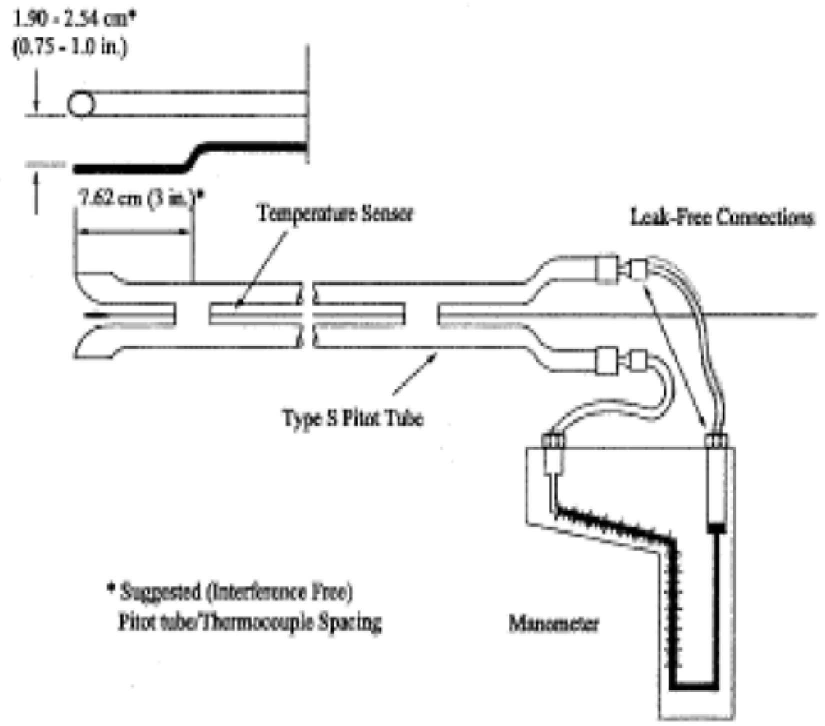
USEPA METHOD 2

STACK VOLUMETRIC FLOW

- Pitot tube (s-type) with manometer to measure differential pressure (Dp)/Velocity Pressure

VP = TP – SP

- dP >0,05” H_2O or micromanometer (not preferred)
- Thermocouple to read stack temperature.
- Highly fluctuating flows due to consistent (non-batch) process changes. Pressure dampening systems.
- Batch operations – minimum duration of each test run will include at least one cycle.
- Pitot tube calibration procedures – keep them in good condition.
- Calculates volumetric flow (acfm) based on M1 velocity, cross-sectional area of stack, stack temp (scfm) and moisture (dscfm).



USEPA Method 4

STACK MOISTURE

- Used to determine moisture content (%) of exhaust gas.
- Water is condensed out of gas stream in ice-cooled impingers.
- Volume of gas is measured through a dry gas meter.
- Gravimetric or volumetric measurement of moisture catch (scale or graduated cylinder).
- %Moisture = %Moles Water/Moles of Exhaust Gas
- Volume of liquid anticipated in PFAS Train (assume 120 min test and 90 CF):

SOURCE TYPE	APPX %MOISTURE	VOLUME OF CONDENSATE
Coating Line	2 – 5%	50 – 100 ml
Incinerator	10 – 15%	200 – 300 ml
Caustic Scrubber	25 – 50%	600 – 5000 ml

High variability based on source temp and other factors – recommend preliminary measurements before test!

USEPA Method 25A

TOTAL HYDROCARBONS

- Flame ionization Detector is used to measure total hydrocarbons (THC) at PPM levels.
- Inlets run 1000 – 10000 ppm
- Outlets run 10-100 PPM.
- Analyzers measure real-time.
- VOC HAPs generated must be measurable (have response) with FID.

PREPARING FOR THE STACK TEST

- A comprehensive test plan should be developed and reviewed to ensure agreement with procedures.
- Sample plans should consider:
  - Safety and Health (WAH, Hoisting/Rigging, Hazcom, physical exposure hazards, etc.)
  - Stack dimensions (diameters, port extensions, straight run distances, etc.).
  - Power needs (at stack, at recovery area and at mobile lab).
  - Stack flows and moisture, velocity pressures, anticipated concentrations, test durations.
  - Logistics (stack port access and dimensions, distance from ground level and trailer, hoisting needs)

PREPARING FOR THE STACK TEST

Coordinating Process Operations and Test Scenarios (durations of tests vs. duration of production)

Batch operations – must include at least one full cycle and should consider:

- Duration of a batch
- Number of cycles per batch
- Peak emission points and anticipated concentrations

PREPARING FOR THE STACK TEST

Coordinating Process Operations and Test Scenarios (durations of tests vs. duration of production)

Continuous Production – Typically worst-case operating scenarios are required to demonstrate compliance.

- Ensure adequate raw material and production needs are available for test.
- Coordinate operational metrics and recording of process data.
- Determine peak-operational periods for testing.
- Ensure steady-state operation.

Examples

Fuel cell manufacture – capture - permanent total enclosures along an assembly line. Control is a regenerative thermal oxidizer.

Food sterilization – capture system - evacuation chamber, control system - caustic wet scrubber

Film coating line – permanent total enclosure and regenerative thermal oxidizers used for VOC/HAPs capture –

Coating operation – capture – total or partial enclosure, control - thermal oxidation

PFAS destruction – supercritical water oxidation, emerging technology to control PFAS

Conclusion

HAPs Capture & Control are tools not commonly thought of as traditional IH, but incorporate many techniques and concepts to evaluate, such as

- Stack testing
- Flow measurement
- Airborne concentrations

The IH can play a key role in the design of systems and understanding these systems can help understand issues around potential worker and community exposure issues.

REFERENCES

https://www.epa.gov/air-emissions-monitoring-knowledge-base/monitoring-control-technique-capture-systems