Title: Isobutylene Proves Successful in a Unique Process Tool Tracer Gas Test

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Abstract

This article presents a case study describing the use of an inexpensive, simple and reliable method to quantitatively evaluate the ventilation provided to a corrosive cleaning process tool. Although face velocity measurements are recommended by the SEMATECH Application Guide for SEMI S2-93, the unique design of the process tool precluded the use of traditional ventilation measurements. This work offers a simple, inexpensive technique that may be useful in a wide variety of other applications.

Introduction

The Quartzware Cleaner is a two chamber-enclosed system designed for the cleaning/etching of diffusion furnace quartzware and related equipment. A typical processing regimen for this tool includes an etch cycle using HF/HNO_3 and a de-ionized water rinse, which is then followed by an air purge cycle to dry the cleaned equipment. Parts to be cleaned are mounted into one of two chambers, where corrosive spray is applied to either rotating (Carousel) and/or stationary (Tube) parts. The corrosive etch solution drains to an acid /disposal system utility, thus spent solution does not accumulate within the chamber. Corrosive vapors are removed by the ventilation system, which is designed to run continuously though all cycles at the manufacturer's design specification of 0.75 inches (water gage) static pressure at the exhaust manifold. Both parts chambers are served by a single exhaust plenum, which provides a top-mounted connection for a 10.75-inch interior diameter exhaust duct. The rear of the process tool includes a plumbing compartment which is utilized for the plumbing and delivery of process materials and utilities. The plumbing compartment, which is isolated from the process chambers, features secondary containment and a leak detection system. The volume of the left chamber is approximately 30.5 cubic feet and the volume of the right chamber is approximately 22.3 cubic feet.

With respect to the SEMATECH Application Guide for SEMI S2-93, the process tool is classified as a wet station or parts clean hood with an exhaust type classification as "high corrosive." Recommended test methods for this product classification includes face velocity measurements and vapor visualization. Due to the unique design of the tool, face velocity measurements would not provide reliable ventilation quantification since each chamber is serviced by a common exhaust plenum, chambers are closed during operation, and makeup air enters from the lower region of each chamber. In addition, the manufacturer wanted to evaluate the velocity of air moving through each chamber to provide an indication of capture efficiency.

To quantify ventilation, it was desirable to select a test method that could meet or exceed the SEMI S2 Guidelines.

The test method selected for ventilation evaluation and quantification included tracer gas analysis as the primary method, and duct velocity measurements as the secondary method. (Note: vapor visualization was also used, but the technique is not presented in this paper.

Methods and Materials

Tracer Gas Overview

The theoretical basis for this technique is based upon the law of conservation of mass and energy, e.g. air flow into a zone is equal to outflow. Therefore, the concentration of a gas or vapor at any time can be expressed by a differential material balance, which provides a basis for relating ventilation to the generation and removal rates of a contaminant. In the case where a volume of air is contaminated and there is no further generation of the contaminant within the volume of air, the rate of decrease of concentration over a period of time can be related to the ventilation rate (Grott, et al), as defined in Equation 1 below.

Where:

V = volume of the enclosed space

C = concentration of the gas at time t (seconds)

Q = air flow into the zone

and the volumetric air exchange rate in seconds is defined in Equation 2 below.

By releasing a volume of gas into a chamber and measuring its decay over time, the air exchange rate can be quantified by plotting the natural log concentration data over time and statistically analyzing the decay plot. The basic assumptions (Grott, et al) leading to the derivation of the above relationships are as follows:

- The air in the chamber is of uniform density, which is independent of its spatial position in the enclosed space,

- the average concentration in the zone is the same as the average concentration of the tracer in the airflows out of the zone, and

- the air within the zone is well mixed.

Tracer Gas Methods

The tracer gas method incorporated real time monitoring of isobutylene within each chamber via a Photovac Microtip 1000 photo-ionization detector (PID), Serial NO. NA920007, calibrated to 100 ppmv isobutylene. Calibration was performed by Enviro Services and Repair of Concord, California. With the ventilation off, the tracer is first injected into the chamber of interest using a compressed tracer gas standard equipped with a regulator and sample injection tubing. The tracer injection in the left chamber took place within the lower third region of the chamber, and in the right chamber, the tracer was initially injected within the lower third, and then at the approximate midpoint of the chamber. In all cases, the injection tube was pointed up during injection to maximize the distribution of the tracer within the chamber. The tracer standard used for investigation was 1994 ppmv (± 2%) isobutylene. After tracer injection, the

PID was connected to the injection tube to measure initial concentrations. With tracer concentrations at a steady state, the ventilation system was activated. (Note: since diffusivity in air is measured in $10eE^{-02}$ square centimeters per second (cm^2/s), tracer distribution within the chamber equilibrates relatively quickly.) Tracer gas concentrations were then monitored and recorded at 3-5 second time intervals under conditions of ventilation. This process was repeated twice for each chamber.

During tracer testing, the ventilation system was conservatively operated at approximately 0.70 inches water gauge (negative pressure within the process tool), which is just below the manufacturer's recommended specification of 0.75 inches.

Ventilation Test Methods

Testing was completed within the manufacturing area at temperatures ranging between 78-82 degrees Fahrenheit. For purposes of calculations, atmospheric pressure is assumed. The process tool was connected to a blower via a circular 12-inch diameter flexible exhaust duct. Onsite engineers adjusted the blower exhaust rate to achieve a 0.7-inch negative pressure within the tool's exhaust plenum.

Duct velocity measurements were conducted using an AirData Multimeter ADM-870 Serial NO. M93333 electronic micromanometer, provided by IDC Inc., of San Jose, California. The measurements were conducted in a short and relatively straight run of primary exhaust duct at approximately seven duct diameters downstream of the process tool. This location was selected to minimize the potential effects of turbulence caused by the transition between the process tool exhaust plenum and the exterior primary exhaust duct. However, the measurement point was also located between slight bends in the ventilation duct. Since the exhaust duct was flexible (corrugated texture) and because of potential turbulent interference due to the "between bend" measurement point location, only a center point velocity measurement was taken. In the absence of a duct traverse, the measurement data is considered qualitative. Its sole purpose is to provide a point of comparison to the quantitative tracer gas data. The duct configuration would be expected to generate friction and turbulence at measurement points near the sides of the duct. It is expected that this process tool, when installed in a fab facility, would use different duct materials and exhaust configurations. The duct measurements provided in Table 5 should not be construed to be representative of an installed facility's ventilation system.

Results

The tracer gas data are summarized in Tables 1 and 2. Figure 1 demonstrates the tracer concentration versus time for the left chamber second run. A regression analysis of the natural log concentration versus time data produced best fit lines for each tracer run. For each chamber, the slope from each run is averaged to produce an average volumetric air exchange rate for the chamber. Regression parameters are summarized in Table 3 and calculated chamber ventilation rates are provided in Table 4. Using the tracer gas data, the total ventilation provided to the process tool is calculated at 704 cubic feet per minute (cfm). The left chamber was found to be exhausted at 450 cfm, and the right chamber at 254 cfm, or 14.8 and 11.4 air changes per minute respectively. Centerline duct measurements compared favorably to the tracer results and yielded an average total exhaust rate of 724 cfm.

Based on chamber dimensions, the closed chamber air velocities (within chamber) are at least 96 and 74 feet per minute for the left and right chambers respectively. As tested, the ventilation is designed to optimize the use of airflow to capture and exhaust chemical vapor emissions generated during processing. Under use conditions, chamber air velocity will increase due to reduced volume of chamber air displaced by parts to be cleaned.

Conclusions

The process tool ventilation system was conservatively and quantitatively tested under normal operating conditions. The evaluation methods included tracer gas analysis and qualitative duct velocity measurements. The tracer method chosen proved to be simple, reliable and inexpensive (with material and equipment costs less than $300). The tracer gas technique also provided a convenient way to measure airflow within each chamber. Airflow into each chamber could not be reliably quantified using face velocity measurements.

References

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List of Equations, Tables, and Figures