

Environmental Compliance Testing of Fuser and Pressure Roller Products for Digital Printers

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Abstract

Printer manufacturers are required to meet a number of environmental standards for materials utilized in their products and the emissions of those products in a work place environment. Legislative compliance, such as ROHS and California Proposition 65, establish the maximum allowable amount of controlled substance, or maximum exposure of a released substance within a work place air space. These demands have filtered down to the vendors of components used in the printer. This requires that component manufactures verify that their products do not contain, nor emit into the working environment, substances exceeding compliance regulations. In order to meet these requirements, testing at the temperatures that the component sees, in an operating printer, needs to be completed and the results compiled to determine environmental compliance. Environmental compliance testing protocols and testing equipment used for identifying and quantifying emissions, dynamic "headspace testing", of fuser and pressure rollers at operating temperatures are discussed. Particular attention is given to benzene, toluene ethylbenzene, xylene (BTEX compounds), acetaldehyde and formaldehyde.

Introduction

Materials used in fuser and pressure rollers, such as silicones, fluorocarbons, fluoropolymers, paints, and epoxies operate at elevated temperatures (150°C - 250°C) within the printer. At these temperatures, emission of volatile organic compounds (VOCs) may occur. Low molecular weight carbonyls such as formaldehyde can be evolved "in-situ" by high temperature oxidation. These emissions add to the emissions of a printer from toner, silicone oil and greases, to give a total printer emission profile. The Environmental Protection Agency (EPA), National Institute of Occupational Safety and Health (NIOSH), The California EPA and the European Union set office equipment emissions regulations. Regulations setting the maximum exposure to individual VOCs in indoor air have been set by these regulatory agencies under laws such as the California Proposition 65 and the European Union ROHS and REACH directives. Headspace emissions testing of printers have been conducted in large environmental chambers [1] [2], under conditions simulating an office environment. The contribution of each printer component can be determined by chamber testing under the temperature conditions seen in a printer. Results from testing give both the component manufacturer and printer manufacturer the ability to control and reduce total emissions.

Headspace testing of fuser and pressure rollers for VOCs/BTEX and the aldehydes, formaldehyde and acetaldehyde, are conducted at operation temperature with qualitative and quantitative analysis of the eluted compounds.

Materials and Methods

Test equipment used in the headspace testing lab consist of a Hewlett Packard 5890A gas chromatograph (GC) equipped with a Flame Ionization Detector (FID) and a HP 5971 Mass Spectrometer (MS); a Tekmar 3000 Purge and Trap Concentrator, an ultra high purity (UHP) air generator, a 14 liter stainless steel chamber, and helium gas supply.

The 14 liter stainless steel headspace chamber is an airtight unit continuously purged with air generated by the UHP air generator at 100 to 200ml/min flow rate. The chamber is large enough to hold a 15cm diameter x 65cm length roller. The chamber is heated in a BlueM oven rated to 300°C to heat the roller to operating temperature, which is monitored and recorded.

The Tekmar 3000 Purge and Trap thermally desorbs the analytes adsorbed onto the sorbent material by heating the trap to 260°C while purging with carrier gas at 40mL/min for 3 minutes and injecting the purged gas directly into the gas chromatograph. Qualitative identification of the analytes is done with the HP 5971 Mass Spectrometer and the quantitative identification is processed with the Flame Ionization Detector. Gas Chromatograph capillary columns employed are specific to the test method used. Figure 1 shows the general layout of the test lab equipment.

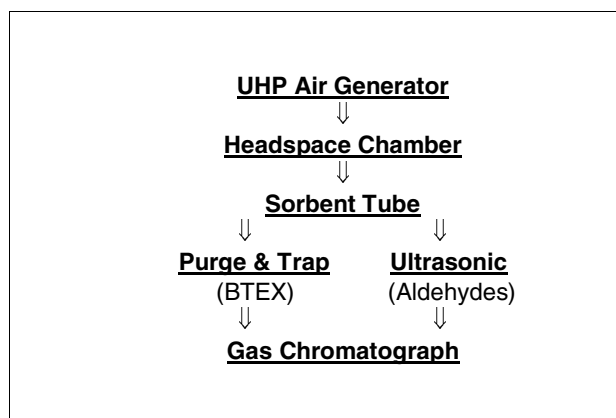


Figure 1. Headspace Testing Lab Equipment flow diagram

The GC/MS/FID conditions are:

- Aldehydes: DB-WAX column (PEG st. phase) 15m length, 0.25mm ID, 0.5µm film. Oven profile 70°C for 0.5 min, 10°C/min to 200°C for 10 min. FID used for quantitation.
- BTEX: HP-VOC column (cyanopropyl-polysiloxane st. phase) 30m length, 0.2mm ID, 1.12µm film. Oven profile 35°C for 6.0 min, 5.3°C/min to 150°C, 10°C/min to 240°C. MSD for screening, FID for quantitation.

The test methods followed for the GC are:

- NIOSH Method 2538, Acetaldehyde by GC/FID [3]
- NIOSH Method 2539, Aldehydes Screening [4]
- NIOSH Method 2541, Formaldehyde by GC/FID [5]
- NIOSH Method 2549, Volatile Screening [6]

The California Code of Regulations, Title 8[7], recommended air volume collection of 24L at a sampling rate of 0.1L/min is taken into consideration, and adjusted for the headspace chamber of 14L, for all reporting results.

The sorbent tubes used for VOC/BTEX collection were BTEX Trap J, manufactured by Supelco. The tubes are thermally desorbed at 260°C for 3 minutes by the Purge & Trap and injected automatically into the GC for analysis.

NIOSH Methods 2541, 2538 and others, depending upon equipment and methodology, govern the collection and analysis of formaldehyde and acetaldehyde for GC/MS/FID. Methods 2541 and 2538 use the derivatized form of formaldehyde and acetaldehyde for analysis because of its inherent stability. The sorbent tube is ORBO-23 (Supelco) (XAD-2 silica gel coated with 10% w/w 2-hydroxymethylpiperidine 2-HMP with 120g front section / 60mg back section; 20-40 mesh.) The sorbent material is desorbed in toluene and then placed into an ultrasonic bath for 60 minutes. The evolved oxazolodine is removed from the sorbent tube and 1µL aliquot is injected into the FID and 0.1µL into the MSD for analysis, in accordance with Methods 2538 and 2541.

Calibration curves were obtained using standard formaldehyde oxazolodine derivative (2000µg/ml) and diluted down to target concentrations, 1ng/ml -200ng/ml. A 1.0mg/ml solution of formaldehyde was standardized per Method 2541 and diluted to the target concentrations.

Recovery of the system was determined by placement of 20, 50 and 100ng/ml of formaldehyde in isopropanol into the chamber and heated to 200°C. This was repeated with collection times of 60, and 90 minutes.

Emissions Test Reporting Protocol:

- ❖ Qualitative analysis (identification) of all compounds eluting the GC/MS with masses 30 through 250.
- ❖ Qualitative analysis of all compounds with area counts greater than 30,000.
- ❖ Quantitative analysis of all compounds with area counts greater than 100,000.

- ❖ Quantitative identified chemical emissions standards for each compound with 5-point calibration curve per NIOSH, ASTM or established calibration standards.
- ❖ Aldehyde levels greater than 100ng/tube per 22.4L air sample to be reported. This equates to 62ng/tube for 14L chamber with 70% recovery.
- ❖ Results to be reported as a function of mass eluted vs. time. Sequential time intervals at 15, 30, 45, 60 and 90 minutes are reported.

Results and Discussion

Emission results for BTEX and other VOCs are screened over a 60 minute sampling period using the MS detector, per Method 2549, and are fairly straightforward. Testing did show a significant presence of toluene emitted from a paint used on a fuser roller. Process changes were implemented that reduced the emission count from 435,000 to 3000, well below the protocol reportable limit.

Aldehydes detection presented more of a challenge because of the low concentration levels needed to be detected, and the reactive nature of aldehydes. Figure 2 shows examples of formaldehyde emissions detected over a sequential sampling period of 90 minutes, per protocol, for three different rollers tested separately under different temperatures. The testing protocol for formaldehyde emissions, 62ng/tube (“limit” in Figure 2), establishes the maximum allowable limit for a roller in the 14L chamber, with 70% recovery. This calculation is derived from the California Proposition 65 “Safe Harbor Levels” [8] and California Code of Regulations [7] exposure limits for formaldehyde. Chronic effects for formaldehyde are stated at exposure levels of 3µg/m³ (2ppb) [9]. This test showed that neither the fuser roller nor the two back up rollers exceeded the protocol limit during any sampling period. Similar results were found testing other rollers of the same part number.

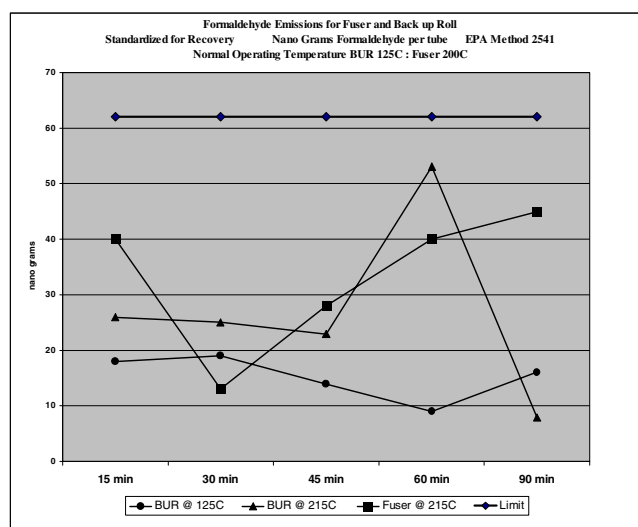


Figure 2. Example of Formaldehyde Emissions from a fuser and a back up roller at operation temperatures

The recovery capability of the system was found to be 70% for aldehydes with calibration standards per Methods 2541. While detection results were repeatable above 20ng in the calibration phase, questions arose at levels below 20ng, because of inconsistency in the blank sorbent area counts. The same variation was seen with spiked sorbent at the 10ng level and below, which may be an indication of the limit of resolution for these methods. Calibration of, and testing for aldehydes at the protocol reporting limit of 62ng per sorbent tube, was stable and repeatable, giving confidence to the NIOSH methods at such low levels of detection. Figure 3 shows a normalized calibration curve with the average baseline of blank sorbents and blank chamber set at zero. Area counts for concentrations 20ng and above fit a linear profile.

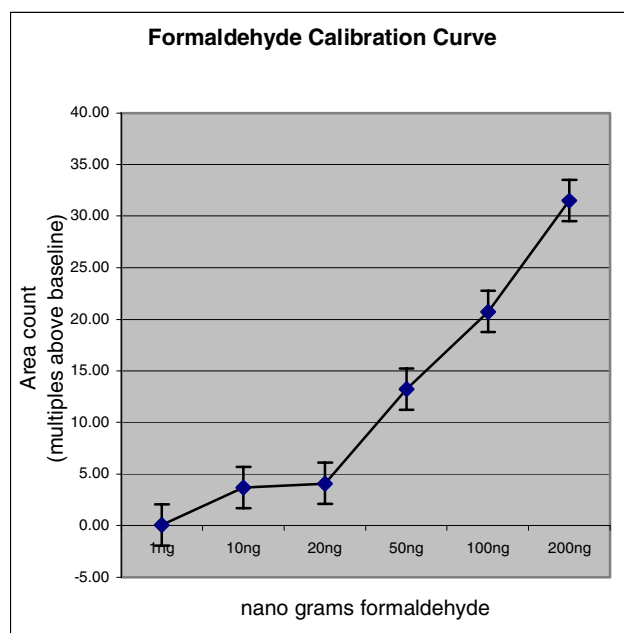


Figure 3. Formaldehyde Calibration Curve

Conclusions

Fuser and pressure roller emissions can be readily identified and quantified using a headspace chamber and established methods of analysis. NIOSH Methods 2538, 2539, 2541, and 2549 were substantial methods to follow using GC techniques. They provided the needed resolution to meet reporting protocol for headspace chamber analysis of fuser and pressure rollers.

Results of component headspace testing give the printer manufacturer data that can be incorporated into a computer model of total printer emissions, as well as the simple fact that the component is in compliance with emissions regulations. Testing also gives information on the effects of individual materials, which then can be processed to reduce or eliminate emissions from that material in the final fuser or pressure roll.

Identification and quantification of emissions of a printer product is becoming a corporate responsibility that will be shared

by the printer component manufactures. Product emissions testing are one aspect of total quality, and can be a supportive function to total quality programs of ISO:9001:2000 and ISO:14001:2004. Commitment to improving product quality demands understanding and control of environmental emissions to meet regulatory compliance.

References

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Biography

Wade Eichhorn has 30 years development experience in laser system design, electrophotographic imaging and, for the past 12 years, design and manufacturing of fusing system rollers. Dave Winters is an analytical chemist with experience in material science testing. In the past 12 months, the authors have created an analytical testing lab, which includes product emissions testing for environmental compliance. Having the in-house capability for air quality environmental compliance has given insight to testing protocol and the demands placed upon our customers for compliance.