

## CHAPTER 9

# The Effect of "Building Bake-Out" Conditions on Volatile Organic Compound Emissions

Charlene W. Bayer

### ABSTRACT

The effects of elevated temperatures on volatile organic compound emissions from particleboard and modular office partitions were investigated. This preliminary study employed large-scale environmental chamber techniques in order to achieve precise control over environmental conditions and background volatile organic compound emissions.

### INTRODUCTION

Building materials and furnishings are significant sources of airborne volatile organic compounds (VOCs) indoors.<sup>1</sup> Frequently, the levels of VOCs emanating from a product will lessen with increasing product age, as can be seen in Figure 1. Figure 1 shows the VOC emission pattern from (1) a new modular office partition, and (2) the same partition after aging for 4 months at room temperature. The total VOC emissions were reduced 79% after aging.

In an effort to accelerate the natural aging process of building materials and furnishings, "building bake-out" has been suggested. This process involves the elevation of the ambient building temperature for several days and also possibly increasing the building ventilation rate. Girman<sup>2</sup> has reported the results of studies he has conducted where he has "baked-out" buildings. He observed a significant reduction in total VOC concentration after a bake-out. He did find that the individual concentration of selected VOCs showed less of a decrease.

The procedures used to perform the bake-out may significantly influence the effectiveness of the technique to reduce the VOC concentrations. The bake-out is

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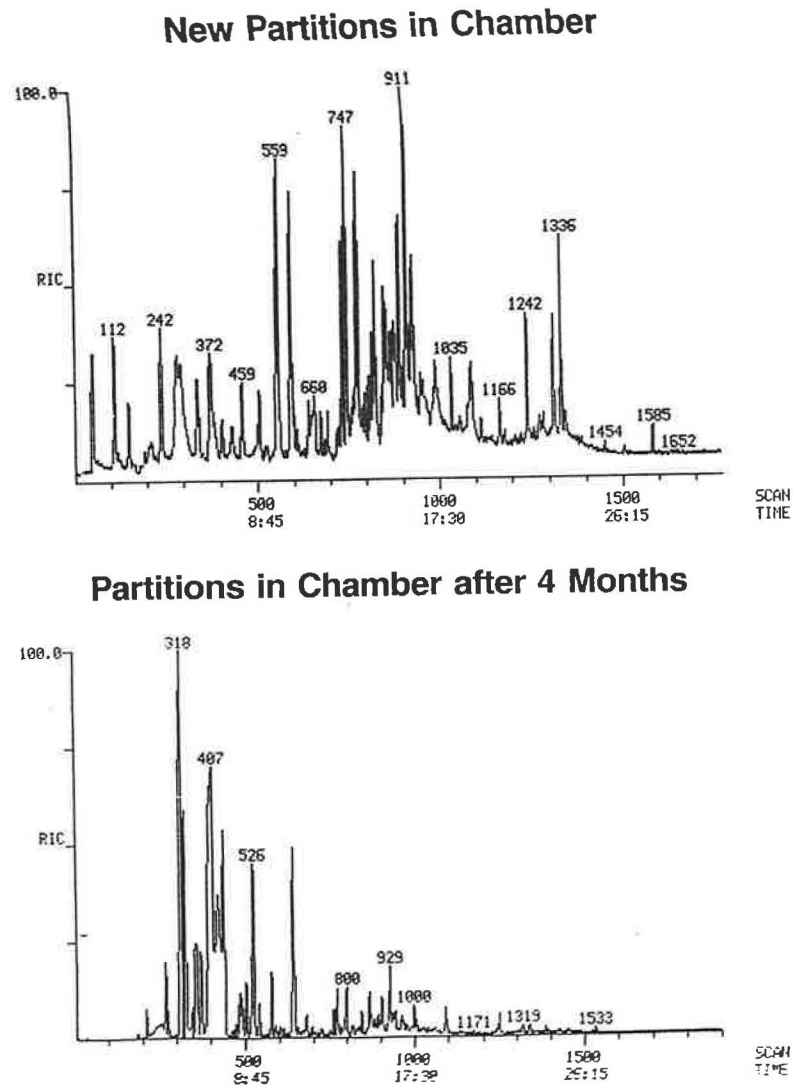


Figure 1. (Top) VOC emission pattern from a new modular office partition. (Bottom) VOC emission pattern of same partition after four months at room temperature.

Table 1. Environmental Chamber Conditions

Volume	28.4 m <sup>3</sup>
Temperature	100-120°F (bake-out) 75°F (pre-bake-out) 75°F (post-bake-out)
Humidity	50% RH
Air change rate	0.5 ACH
Product loading factor	0.56 m <sup>2</sup> /m <sup>3</sup> (partitions) 1.20 m <sup>2</sup> /m <sup>3</sup> (particleboard)

controlled by the duration of the bake-out, the indoor air temperature actually achieved during the bake-out, and the ventilation rate during and after the bake-out. The elevated temperatures must be maintained long enough for the various materials in the building to achieve the elevated temperatures. Girman<sup>2</sup> found that it took approximately 3 d for the internal temperature of the building to reach the bake-out temperature. Sufficient ventilation is required to dilute and remove the airborne pollutants emitted into the atmosphere during the bake-out procedure; otherwise the outgassed compounds will be reabsorbed by various building materials and furnishings. If the ventilation rate is too great, then an elevated indoor temperature will not be achieved.

The effect of these and other factors on the VOC emissions from particleboard and modular office partitions, two common building materials and furnishings, were investigated using large-scale environmental chamber techniques. The studied materials were subjected to elevated temperatures while monitoring the VOC emissions. VOC emissions were measured before, during, and after the bake-out procedure.

## EXPERIMENTAL

### Bake-Out Conditions

The materials to be sampled were loaded into an environmental chamber, 28.4 m<sup>3</sup> in volume, with temperature, humidity, and air change rate control.<sup>3</sup> The environmental chamber conditions employed are listed in Table 1. The pre-bake-out conditions were maintained for 2 to 4 d. Depending on the experiment, the chamber temperature was maintained at 100°F (88°C) and 120°F (99°C) for 3 to 5 d. The post-bake-out conditions were maintained for 2 d. Materials to be tested were loaded into the chamber and conditioned for 24 h prior to emission testing.

### Solid Sorbent Tubes

Volatile organic compounds were collected on two different multilayer solid sorbent tubes. Both tubes were prepared in Pyrex glass tubing 17.8 cm in length, 2 mm internal diameter. The first solid sorbent tube used was a three layer tube containing glass beads, Amersorb XE 340, and Tenax<sup>®</sup>. The preparation of these tubes has been described elsewhere.<sup>4</sup> The second multilayer solid sorbent tube was

a four-layer tube containing 0.25 g glass beads, 0.15 g Carbotrap C, 0.20 g Carbotrap, and 0.20 g Carbosieve S-III. The layers separated by clean, unsilanized glass wool plugs. The tubes were baked at 300°C for 19 h while being purged with a stream of 20 ml/min nitrogen. The tubes were cooled to room temperature while being continuously flushed with nitrogen. The tubes were then stored in clean, baked glass containers with PTFE-lined screw caps. These containers were used for transportation of the sampling tubes to and from the sampling site.

### Sample Collection

The VOC analytes were concentrated on the solid sorbent sampling tubes by drawing chamber air through the sorbent tube at 200 cc/min for 60 min using personal sampling pumps.

### Analysis

The solid sorbent tubes were analyzed by thermal desorption/gas chromatographic/mass spectrometric (TD/GC/MS). This was accomplished with a Tekmar Model 5010 thermal desorber interfaced with a Finnigan OWA 30B GC/MS. The desorber is equipped with a cryofocusing unit to trap volatiles on a length of deactivated aluminum-clad, fused silica capillary tubing (3 m × 0.20 mm I.D.). The fused-silica trap was connected to a DB 624 (J & W Scientific, Inc.) capillary column using a glass butt-end connector. The following conditions were used for thermal desorption: prepurging of the tube for 5 min at 42°C; desorption at 290°C for 10 min; cryotrap cooled to -150°C with liquid nitrogen during desorption and transfer through the transfer line; transfer temperature 290°C for 3.5 min; valve temperature 290°C; injection temperature 290°C; and injection time 0.75 min. The GC separation was begun immediately following flash evaporation from the fused silica trap onto the head of the capillary GC column using the following temperature program: 30°C isothermal for 1 min; 8°C/min to 220°C; isothermal for 10 min. GC/MS transfer oven temperature was 275°C. Mass spectral data were collected between 42 and 300 amu in 0.7 sec. External standards were prepared by injecting known concentrations of the analytes of interest loaded onto solid sorbent tubes as gaseous standards using static dilution bottle techniques.<sup>4</sup> The external standards were analyzed under identical conditions as those used for the sample tubes.

## RESULTS AND DISCUSSION

The initial bake-out study was conducted on modular office partitions that had been removed from an office building known to have volatile organic compound contamination. The partitions had adsorbed VOCs from the building in sufficient quantity to have a strong VOC odor similar to that in the building. These partitions were subjected to bake-out conditions in order to determine whether mitigation of the partitions by using bake-out procedures was possible. In this first experiment,

the two sampling locations were outside of the environmental chamber. The pre-bake-out period was continued for 4 d to ascertain that constant VOC emissions patterns were occurring. Emissions were highest the first day of the sampling in the pre-bake-out phase, but a constant emission pattern was obtained after the second day. The VOC emission patterns obtained in the 3 d of the pre-bake-out phase are depicted in Figure 2. The temperature inside of the chamber was then raised to 120°F while maintaining the ventilation rate at 0.5 ACH. The emissions of the VOCs increased significantly for the first 2 d of the bake-out. The reconstructed ion chromatograms (RICs) of this phase are shown in Figure 3. On the third day of bake-out, the VOC emissions appeared to lessen, particularly of the higher molecular weight and more polar compounds. This reduction in emissions continued until the sixth day of bake-out when no VOCs were detected, Figure 4. Selected VOCs identified at various sampling intervals during the study are given in Table 2. It was discovered that water was condensing in the sampling lines so that water was being preferentially collected by the sorbent tubes. The water condensation was occurring since the sampling lines were at a cooler temperature than the temperature inside the chamber. An attempt was made to purge the water from the sampling lines with helium prior to collection to alleviate the problem. This did not solve the problem. In this experiment, the VOCs were being collected on the three-layer adsorbent tubes. The adsorbents Tenax<sup>®</sup> and Ambersorb XE 340 have the disadvantage of being extremely sensitive to high humidity conditions. The Ambersorb beads were swelling to several times their normal size from the collection of the water. The collection media was changed to the four-layer solid sorbent tubes. The adsorbents used in these tubes are much less sensitive to high humidity conditions. These adsorbents also have the advantage of fewer artifacts and easier removal of background contamination prior to sample collection. The use of the four-layer tubes did not alleviate the losses of the more polar compounds. These compounds were probably preferentially being dissolved in the water and were not being adsorbed by the sampling media. It was also hypothesized that VOCs were being lost by attachment to mineral salts plating out on the walls of the environmental chamber.

Modifications in the environmental chamber were made to reduce the losses of VOCs to condensation and plating of the mineral salts. A demineralizer was installed on the water supply to the chamber humidifier. The sampling lines were moved inside the chamber so that the sampling lines and sorbent tubes were the same temperature as the chamber air. The solid sorbent tubes were not characterized for their collection efficiency at the bake-out temperatures for this preliminary study. These modifications appeared to eliminate the VOC losses due to condensation and mineral salt plating.

Particleboard samples were then loaded into the chamber in order to study the effects of elevated temperatures on VOC emissions. The pre-bake-out phase was continued for 2 d, then the temperature was elevated to 100°F for 5 days, and post-bake-out phase was conducted for 2 d. Figures 5 and 6 depict the RICs of the three phases. Selected VOCs detected during the three phases are given in Table 3.

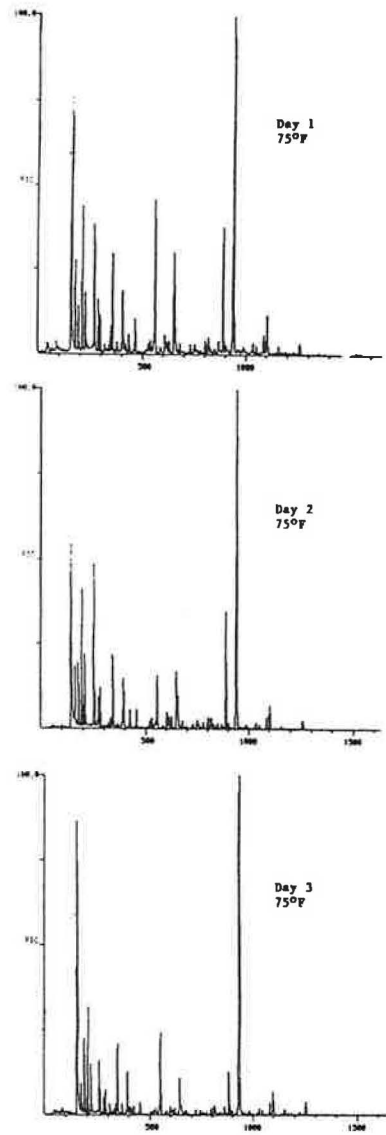


Figure 2. VOC emission patterns from partition before bake-out.

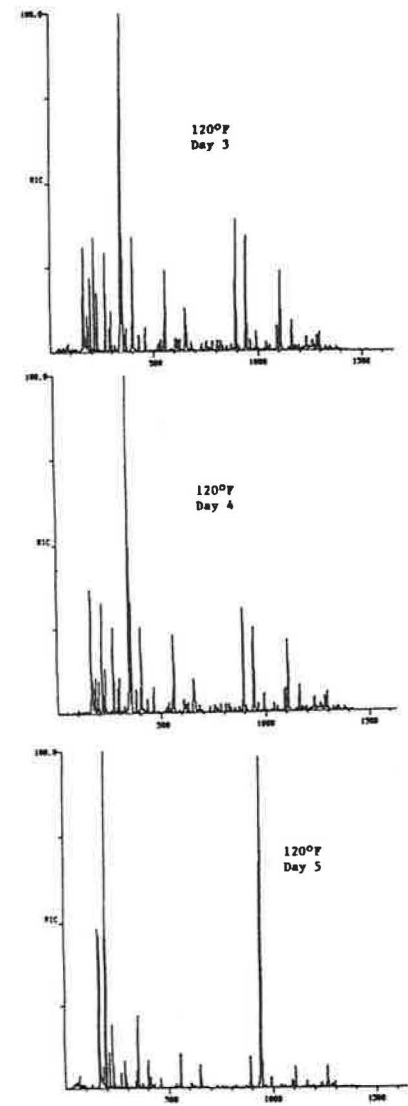


Figure 3. VOC emission patterns from partition during bake-out.

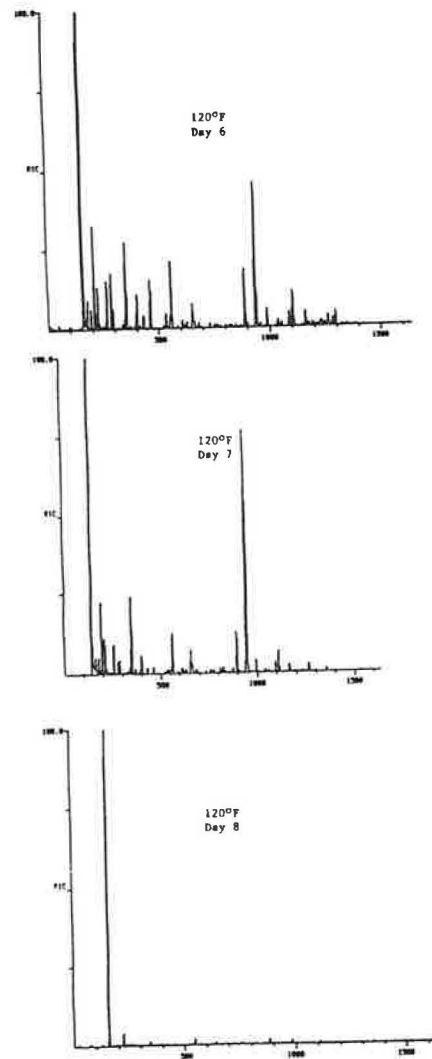


Figure 4. VOC emission patterns from partitions during latter stages of bake-out.

Several higher molecular weight compounds were detected only in the post-bake-out period. Although reductions of certain VOCs did occur during and following the elevated temperatures, certain VOC concentrations such as toluene and hex-

Table 2. Selected VOC Emission Detected From Modular Office Partitions

Compound	Concentration (mg/m <sup>3</sup> )			
	Pre1	Pre2	During1	During2
Ethanol	0.50	0.71	0.78	0.15
1,2-Dichloroethene	1.7	1.4	6.1	BD
Acetone	21	19	0.29	BD
Hexanes	8.3	27	—	1.5
Trichloroethene	0.60	1.1	3.8	BD <sup>a</sup>
1,1,1-Trichloroethane	0.90	1.6	BD	BD
Benzene	7.0	11	19	4.2
Toluene	8.6	22	45	1.5
Methylene chloride	3.2	9.8	BD	7.5
Xylenes	2.8	9.4	9.1	BD

<sup>a</sup> BD is below detection limits.

anes rose during the post-bake-out phases. Polar compounds, such as phenols, were detected only in the pre-bake-out phases indicating that losses of polar compounds were still occurring. Table 4 gives the total VOC concentrations detected during the three phases of the bake-out procedure in millions of counts. This indicated that the bake-out procedure was unsuccessful at reducing the VOC emissions from the particleboard. Total VOC counts were reduced during the period of the elevated temperatures. This could be the result of changes in the adsorption characteristics of the solid sorbents from the elevated temperatures.

The chamber was loaded with another set of modular office partitions removed from a different area of the contaminated building. The VOC emissions from these partitions rose and dropped off during the elevated temperature phase of the study, but total VOC emission levels reported as millions of counts (Table 5) did not show a reduction.

## CONCLUSIONS

These preliminary studies of VOC emissions from building materials and furnishings seemed to indicate that elevating ambient temperatures around the products to accelerate the aging process was not successful. In the case of particleboard, it appeared that the elevated temperatures may have allowed the release of higher molecular weight compounds into the atmosphere that were not released at the lower temperatures.

These are very preliminary results. Studies on the effect of bake-out procedures on building materials and furnishings are continuing. The effect on the collection efficiencies of the adsorbents from the elevated temperatures and humidities is continuing. The aging processes of various building materials is being further investigated.

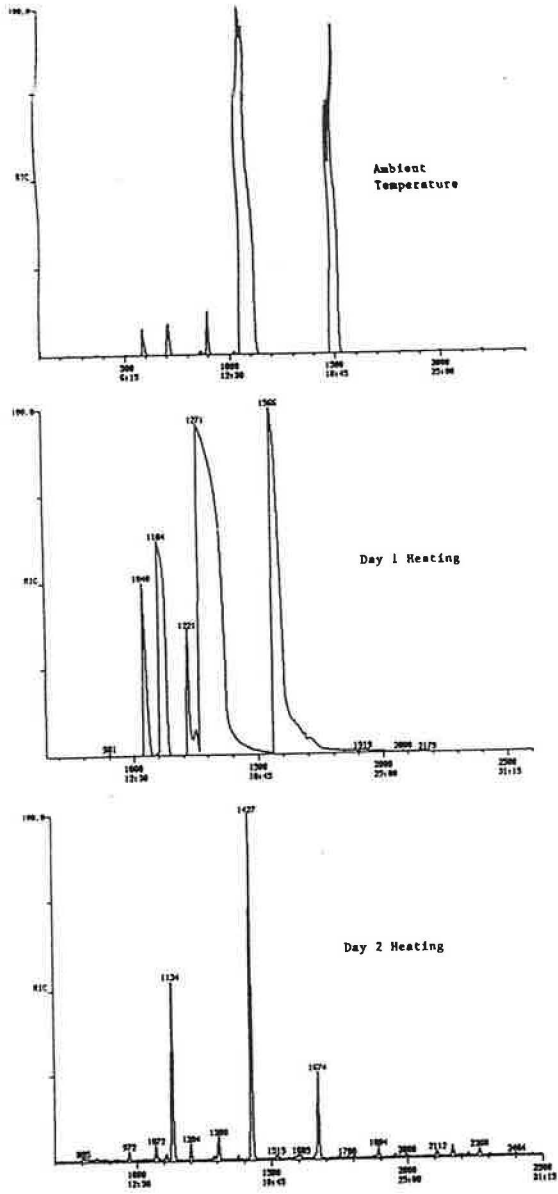


Figure 5. VOC emission patterns from particleboard before and during bake-out.

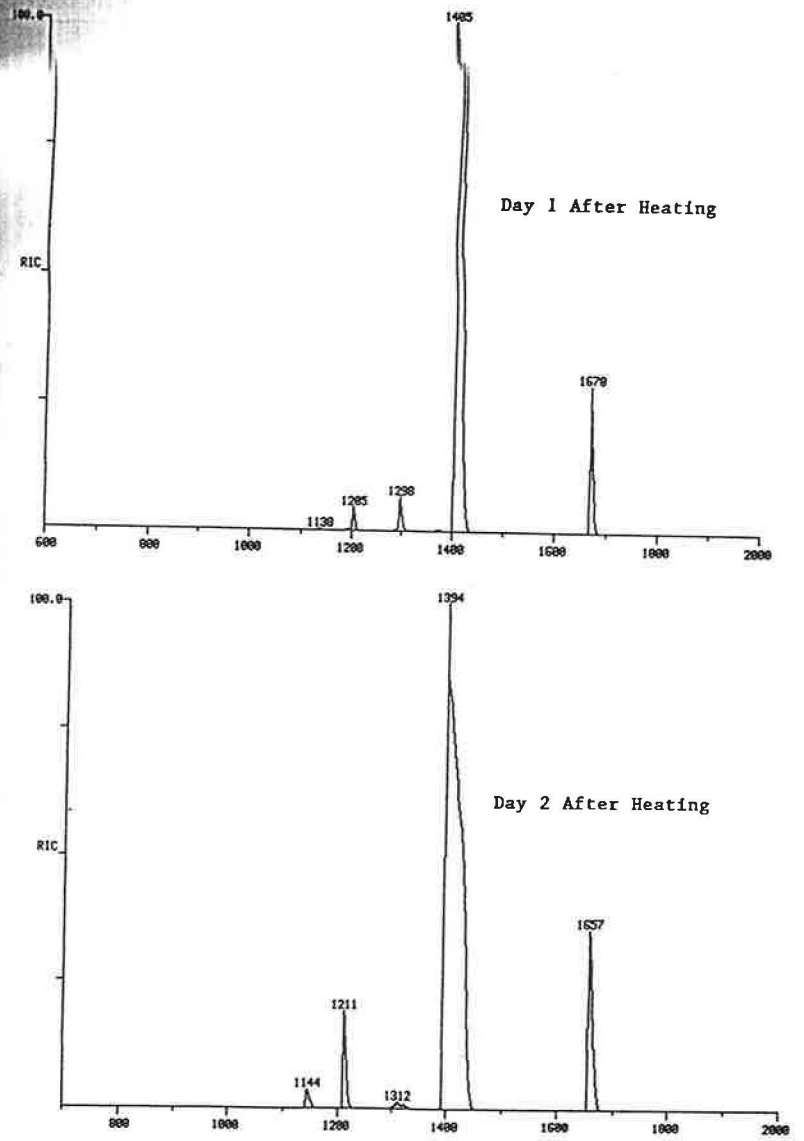


Figure 6. VOC emission patterns from particleboard before and after bake-out.

Table 3. Selected VOC Emissions From Particleboard

Compound	Concentration (mg/m <sup>3</sup> )					
	Pre	Pre	During1	During3	Post1	Post3
Methylene chloride	15.8	83.4	69.7	42.5	19.9	0.742
Hexanes	29.1	26.8	47.8	9.12	283	501
Ethyl acetate	1.97	52.4	12.8	3.16	25.0	24.5
Benzene	322	48.1	252	46.4	1230	24.5
Toluene	934	31.6	73.5	60.2	340	722
Acetone	0.625	2.61	1.18	2.62	—	0.472
Benzaldehyde	9.86	7.97	0.750	BD	BD	BD
Ethylbenzene	0.520	4.05	19.2	BD	BD	BD
Trichloroethene	BD	BD	BD	BD	BD	1.26
3,4-Dichloro-2,5-furandione	BD	BD	BD	BD	BD	0.244
Phenol	BD	4.18	BD	BD	BD	BD
4-Methylphenol	BD	0.996	BD	BD	BD	BD

Table 4. Total VOC Concentrations From Particleboard

	Millions of counts
Pre-bake-out day 1	2.6
Pre-bake-out day 2	4.0
Bake-out day 1	0.04
Bake-out day 2	0.04
Bake-out day 3	0.06
Post-bake-out day 1	1.6
Post-bake-out day 2	3.3

Table 5. Total VOC Concentrations From Partitions

	Millions of counts
Pre-bake-out	0.23
Bake-out day 1	0.73
Bake-out day 2	0.40
Bake-out day 3	0.31
Bake-out day 4	0.30

## REFERENCES

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