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Bake-Out of a Portion of a New High-Rise Office Building

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16. ABSTRACT

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A partial building bake-out was performed in U.S. EPA's new Region IX Headquarters' Building in San Francisco, California in July, 1990. The intent of the bake-out was to reduce indoor air contaminant concentrations associated with residual volatile organic compounds (VOCs) found in a variety of common building materials and finishing agents. Four nearly identical floors from the 21 story office building were heated above 30 °C for 34, 38, 54, and 86 hours to determine the effect of bake-out duration on post-bake pollutant concentrations. VOC and aldehyde sampling was conducted before, during, and after the bake-out. The results indicate that total volatile organic compound (TVOC) source strengths were reduced during the bake-out by 45 - 76 %. Similar reductions in targeted VOC source strengths were also observed from the pre- to post-bake monitoring periods. While the most abundant aldehyde species concentrations increased approximately 65% during the mid-bake monitoring period, post-bake aldehyde concentrations remained similar to pre-bake levels.

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INTRODUCTION

Building materials and finishes commonly used in renovation and construction can emit appreciable concentrations of residual volatile organic compounds (VOCs) into the indoor environment.[1,2] While the concentrations of many of these compounds tend to decrease over time,[3] they remain a concern because many are thought to be responsible for the sensory irritation and fatigue associated with Sick Building Syndrome.[4] Building bake-out, a process which involves the sustained heating of a new or recently renovated structure (e.g., to approximately 30 - 35 °C) to accelerate off-gassing of VOCs, has been suggested as an effective method for reducing the concentrations of these potentially problematic compounds.[5] While many uncertainties concerning bake-out duration, temperature requirements, and optimal ventilation rates remain unresolved, the available data indicate that appreciable reductions in indoor VOC concentrations result from an increase in a building's interior temperature to 32 °C or higher for several days.[6]

Three main objectives were identified for the present study: (1) to characterize the concentrations of selected VOCs and aldehydes in a recently constructed high-rise structure (2) to examine the influence of bake-out duration on the reduction in VOC source strengths observed within a building and (3) to assess the effectiveness of implementing a partial bake-out procedure (i.e., a bake-out involving only a portion of a particular building).

MATERIALS AND METHODS

This investigation was conducted on the mid-level floors of a 21-story office building in downtown San Francisco, California. At the time of the study, floors 1-7 had been occupied for approximately one year by a variety of clerical offices, floors 8 - 12 had just been completed, and floors 13 - 21 were still under construction. Prior to occupancy, the new tenant's management scheduled a bake-out for floors 9 - 12 of the building. If the results indicated a substantial reduction in contaminant concentrations, and the procedure was determined to be manageable by the building staff, bake-out of other areas within the structure was to be considered.

Two separate variable volume air handling systems are located in the study area; one on the 10th floor (serving floors 9 & 10), and the other on the 12th floor (serving floors 11 & 12). Each system consists of a fan room with a filter bank, blowers, and an outdoor air intake, along with the supply and return ducting. The systems are designed to deliver air at 800,900 l/min on the lower floors (9 & 10) and 708,900 l/min on the upper floors (11 & 12). Both systems deliver a minimum of 10% outdoor air; fresh air intakes are located on the eastern side of the building, 10 and 12 stories above street level, respectively. Each floor also has its own heating system consisting of three fan coil units and an independent hot air supply duct located in the plenum.

There is approximately 2,950 m^2 of floor space on the lower floors and 2,560 m^2 on the upper floors. Most of this space is covered with wall-to-wall carpeting, except the northwest quadrant of the 11th floor and several small storage rooms on each floor, which are tiled. Most of the final construction activities, including painting and installation of carpeting, were completed three to six weeks prior to pre-bake testing. Some minor activities (e.g., installation of the cove moldings) continued up until the day before pre-bake monitoring. In addition to a single set of freight elevators, the building has a staggered set of passenger elevators. One bank serves floors 1 - 11, while the other serves floors 11 - 21.

Bake-out

Previous studies have demonstrated that bake-out duration is approximately proportional to the degree of contaminant reduction achieved.[6] In this study two different heating periods were employed in the same

building: the upper floors (11 & 12) were scheduled for a 108-h heating period, and the lower floors (9 & 10) were scheduled for 73 h of heating.

Since recent bake-out studies have demonstrated that heating systems in moderate climates can have some difficulty generating and sustaining the high temperatures required for a bake-out,[6] and since these studies have also indicated that elevated air change rates during a bake-out may be less important to VOC reduction than sustained high interior air temperatures, it was decided to close the test floors' fresh air supply dampers to reduce infiltration of cool outdoor air during the procedure. Both air handling systems' fresh air dampers were adjusted to provide the normal minimum flow of fresh air (10%), and then further reduction of fresh air input was achieved by partially covering the intake (approximately 50%) with a sheet metal plate. After initiating the bake-out, however, it became apparent that interior temperatures would not reach target levels unless auxiliary heating measures were instituted. To this end, boiler water temperature (to the fan coil heating units) was increased from 49 °C to 54 °C, and both air handling systems' fresh air intakes were completely covered with the sheet metal plates. This procedure ensured an absolute minimum infiltration rate for the remainder of the bake-out. At the end of the bake-out period, the fresh air dampers in the test floors' air handling systems were set to introduce fresh air at the maximum flow rate for approximately 60 h to accelerate removal of outgassed contaminants and to reduce building temperatures. Twelve hours prior to post-bake sampling, the air handling systems were readjusted to their original pre-bake fresh air flow rates.

Sampling

All integrated and grab VOC samples were collected in precleaned, evacuated Summa™-polished stainless steel canisters following established indoor air measurement protocols.[7] Aldehyde samples were collected on 2,4-dinitrophenylhydrazine (DNPH)-coated silica gel cartridges and were identified and quantified by high-performance liquid chromatography.[8] Temperature and humidity data were collected at each sample site with recording hygrothermographs and recording thermometers.

Air samples were collected on three different occasions during the study: pre-bake sampling on July 26, starting ten hours before the bake-out began; mid-bake sampling on July 29, approximately 60 hours into the bake-out; and post-bake sampling on August 3, about 72 hours after the bake-out was completed. Sampling generally consisted of one 8-h hour integrated VOC and aldehyde sample collected between 8:00 a.m. and 4:00 p.m. in the same south-central locations on each of the test floors. Ambient air samples were also collected on the roof adjacent to the upper floors' (13-21) air intake vent during the pre- and post-bake phases. In addition to the integrated VOC samples, a single VOC grab sample was collected at the primary sampling site on each floor at approximately 11:00 a.m. during the pre- and post-bake phases of the study. The mid-bake sample collection consisted of 8-h integrated VOC and aldehyde samples on floors 10, 11, and 12, approximately 24 h after the temperature on all the test floors reached 30 °C (≈ 60 h into the bake-out). Air change rates were determined during the pre- and post-bake phases of the study by American Society for Testing and Materials sulfur hexafluoride tracer gas methods.[9] Table I is a summary of the sampling conducted during the study. Compound source strengths[1] (S in $\mu g/m^2$ h) were calculated from the measured concentrations by using:

$$S = (C_i - C_o) * V * ACH / FS$$

where C_i is the indoor compound concentration ($\mu g/m^3$), C_o is the outdoor concentration, V is the volume of the floor (m^3), ACH is the number of air changes per hour, and FS is the floor space in m^2.

While every effort was made to prevent unauthorized access to the test floors during the experiment, construction-related activities were discovered between the mid-bake and post-bake sampling periods. On 7/30/90 (the day after the mid-bake monitoring period), workers removed and replaced small sections of tile that covered electric cable access points on the 11th floor and tiled a small storage room on the 12th floor. Both

activities involved the use of tile adhesives and a white gasoline torch. On 7/31/90 (three days before the post-bake sampling period) a single door in the southeast section of the 9th floor was painted with an oil-based enamel paint.

VOC and TVOC Analysis

Canister samples were analyzed for selected target compounds by using an LKB 2091 magnetic sector GC/MS/COMP system operated in the full-scan mode. Separation of compounds was achieved on a 30-m x 0.32-mm i.d. DB-624 column, temperature programmed from -20 to 200 °C at 5 °C/min.

Total volatile organic compound (TVOC) estimates were obtained by integrating the total chromatographic areas encompassed in the retention time window from perfluorobenzene through dodecane. The cumulative area in each chromatogram for mass to charge ratio (m/z) 55 added to that for m/z 57 represented the aliphatic hydrocarbons. Similarly, the cumulative areas for m/z 91 and m/z 105 were combined to estimate total aromatic hydrocarbons. Surrogate aliphatic and aromatic relative response factors (RRF) were calculated from peak areas in calibration standard runs for m/z 55 plus m/z 57 relative to d_6-benzene and similarly for m/z 91 plus m/z 105. Analyte concentrations incorporated into these calculations are sums of the amounts of aliphatic hydrocarbons (octane, decane) and aromatic hydrocarbons (toluene, ethylbenzne, m,p-xylene, styrene, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene), respectively, present in the calibration mixture. As with target compound quantitation, these RRFs were subsequently used to estimate aliphatic and aromatic hydrocarbon levels in the samples. In all cases, the areas of individual chromatographic peaks were summed manually across all appropriate retention times to yield total areas in each m/z channel[10]. This approach includes only compounds that fragment into the specific mass ions indicated. Benzene, which has neither m/z 91 nor 105 ions, is not included, but was measured as a target compound.

RESULTS

The temperature of the upper floors reached 30 °C approximately 20 h after the start of the bake-out; the lower floors, with their larger volume and surface area, required an additional 20 h to reach this level. Temperatures were held at or above 30 °C for 34 h on the 9th floor, 54 h on the 10th floor, 86 h on the 11th floor, and 38 h on the 12th floor. Maximum temperatures for floors 9 through 12 were 32.2, 33.8, 33.9, and 32.0 °C, respectively. Figure 1 represents the temperature profiles of each of the test floors during the bake-out. Degree-hours (°C hours) of heating (the product of the air temperature minus 27 °C and the number of hours at that temperature)[6] were also calculated. With this method, the lower floors (9 and 10) had a combined heating degree-hour value of 223 °C hours, and the upper floors (11 and 12) had a combined heating degree value of 366 °C hours.

Air change rates were fairly constant during the pre- and post-bake monitoring periods, ranging from 1.11 to 1.26 air changes per hour (ACH) on the upper floors and from 0.74 to 0.90 ACH on the lower floors (Table II). As noted above, the fresh air intake vents were partially, and then completely, blocked during the bake-out period to maximize heating within the structure. (Measurements made with the fully blocked air handling system on the 12th floor after the study was completed demonstrated an air change rate of approximately 0.63 ACH.)

Although the extremely short planning period available for this study prevented the preparation and shipment of field spikes and blanks before the sampling was scheduled to begin, performance evaluation samples were prepared and analyzed after the field sampling was completed. The results of these performance evaluation samples (Table III) indicate, with two exceptions (vinyl chloride and styrene), percent bias was generally on the order of 5 - 15%.

Formaldehyde, acetaldehyde, acetone, and hexanaldehyde consistently accounted for about 93% of the mass measured in the indoor aldehyde and carbonyl samples (range 92 - 94%). Concentrations of these four compounds increased between 11 and 110% (mean = 65%) from the pre- to mid-bake measurement period, but their calculated source strengths (which adjust for changes in air exchange rates) changed between -25 and +47% (mean = -2%) from the pre to post-bake sample periods. Average formaldehyde source strengths decreased by 7% during the bake-out. Acetone source strengths increased on the lower floors by approximately 42%, possibly as a result of the unauthorized painting on the 9th floor described above.

Of the 28 targeted VOCs monitored during this study, 1,1,1 - trichloroethane, benzene, toluene, n-octane, ethylbenzene, m,p-xylene, o-xylene, 1,3,5-trimethylbenzene, n-decane, and 1,2,4-trimethylbenzene consistently accounted for more than 95% of the mass of all the targeted compounds in the integrated samples. Together, the mass of these 10 compounds ranged from 6 to 53% (mean = 17%) of the TVOC mass in any single integrated sample. During any given phase of the study, TVOC and individual target VOC concentrations and source strengths sharing a common air handling system generally remained similar (Tables IV - VII).

As illustrated in Table VIII (selected compound concentrations on the 11th floor), both TVOC and individual VOC levels were generally found in highest concentration during the pre-bake measurement period, concentrations decreased during the mid-bake period, and the lowest levels were measured during the post-bake monitoring period. While this general decrease in compound concentration was true for all floors, it was more pronounced on the upper floors (11 and 12), possibly because these floors had much higher initial contaminant levels than floors 9 and 10. Average pre-bake TVOC source strengths on the 11th and 12th floors ($\approx$ 8,378 $\mu g/m^2$ h) (Tables IV & V) were more than three times higher than the average TVOC source strengths on floors 9 and 10 ($\approx$ 2,502 $\mu g/m^2$ h) (Tables VI & VII). On the upper floors, 64% of the initial TVOC level was aromatic, while only 16% of the lower floors' TVOC level was attributable to aromatic compounds. Individual target VOC source strengths were typically higher on the upper floors.

n-Octane and n-decane were the only target compounds that generally increased in concentration from the pre- to mid-bake measurement periods. n-Decane increased on all floors between 59 and 120%, and n-octane increased on the upper floors by 26 - 37%. Both compounds also demonstrated large decreases in source strength in the post-bake monitoring phase (decreases of between 39 and 93% of the pre-bake level). The aliphatic portion of the TVOC concentration also generally increased during the mid-bake monitoring period (2% on floor 12, 64% on floor 11, and 33% on floor 10), while its source strengths decreased in the post-bake measurements (between 25 and 58%). In contrast, the aromatic portion of the TVOC level decreased from the pre- to mid-bake phase by 11% on the 10th floor, 74% on the 11th floor, and by 85% on the 12th floor (Table IX).

After the bake-out, average post-bake TVOC source strengths on the 11th and 12th floors ($\approx$ 2407 $\mu g/m^2$ h) were still more than 89% higher than TVOC source strengths on floors 9 and 10 ($\approx$ 1272 $\mu g/m^2$ h). While individual target VOC source strengths remained similar in the shared air handling zones, the upper floors' individual source strengths were again generally higher than the lower floors'. Specific compounds that consistently showed major reductions in source strength on all the test floors from the pre- to post-bake monitoring periods include n-decane (39 - 93%), n-octane (41 - 91%), ethylbenzene (45 - 95%), m,p-xylene (48 - 95%), and o-xylene (41 - 94%). The TVOC source strengths were reduced by 45 - 76% of their pre-bake levels (Tables IV - VII).

The data from the grab samples are consistent with the integrated sample analysis: Average TVOC source strengths were reduced by 67% on the upper floors and by 38% on the lower floors during the bake-out. (Because no pre-bake grab sample was collected on the 9th floor, data from that floor's integrated sample was used for this calculation.) The TVOC levels from the grab samples were on average within +/- 15% of the

corresponding integrated sample value. Much of this variation is attributable to the pre-bake sample on the 10th floor, which was 43% lower than the corresponding integrated TVOC level.

DISCUSSION

Despite exemplary building owner and tenant cooperation, at least two factors made this building less than an ideal choice for a study of this type: (1) Although the floors scheduled for the bake-out were essentially completed at the time of the study, predetermined moving schedules prevented any of the floor's furnishings (e.g., desks, chairs, computers, etc.) from being present; (2) because the test floors were scheduled for occupation shortly after their completion, the bake-out and monitoring of these floors had to be conducted while construction work was still in progress on the upper floors. However, because this represented a rare opportunity to gather data on a new building commissioning procedure, the study was performed despite these compromises. Another potential problem associated with interpretation of these data is that the ambient air samples collected on the roof (data in Tables VIII and IX) during the pre-bake phase appeared to have been contaminated by a building exhaust vent. Roof top concentrations of 1,1,1-trichloroethane, toluene, and the xylene isomers were from 2 - 5 times higher than some of the levels measured indoors. This being the case, all of the source strengths were calculated by assuming that the pre- and post-bake ambient pollutant levels were equivalent or that any differences in ambient concentrations were negligible. Meteorological data from San Francisco International Airport suggest this assumption is valid, as the pre- and post-bake sampling dates' weather conditions were very similar. In any case, the great reductions in TVOC and individual VOC source strengths documented in this study suggest more significant changes than those attributable to ambient pollutant levels alone.

This study shows that large reductions in TVOC and target VOC source strengths can be achieved during a bake-out conducted with minimal air exchange rates. It is more difficult to conclude, however, that differences in the intensity or duration of the heating period are responsible for the apparent differences in source strength reduction achieved. The percentage reduction of the aromatic portion of TVOC source strength from the pre- to post-bake period on the upper floors (90%) is approximately three times greater than the aromatic reduction on the lower floors (28%). This large reduction is probably related to the initial aromatic levels in the two air handling zones: Pre-bake aromatic source strengths averaged 5347 $\mu g/m^2$ h on the upper floors, but only 406 $\mu g/m^2$ h on the lower floors. This 13-fold greater aromatic burden on the upper floors gives the potential for much greater reductions during the bake-out. Average post-bake aromatic source strengths on the upper floors were 522 $\mu g/m^2$ h while on the lower floors they averaged only 292 $\mu g/m^2$ h. Average aliphatic concentrations decreased on the upper floors by 38% (3031 to 1884 $\mu g/m^2$ h) and on the lower floors by 53% (2096 to 979 $\mu g/m^2$ h) as a result of the bake-out. Taken together, these data do not indicate any obvious advantage to the extended heating period on the upper floors.

One recent bake-out study has shown mid-bake increases in TVOC and target VOC concentrations ranging from 50 - 400% higher than pre-bake levels[5] despite a mid-bake air change rate of 1.59 ACH. This large mid-bake elevation in concentration is generally taken as evidence that the high temperatures are accelerating the volatilization and removal of the contaminants from the structure. The mid-bake sample collection period in that study, however, apparently occurred only 5 - 10 h after heating began within the structure. In contrast, the present study's mid-bake sample period began some 60 h after the bake-out began, approximately 24 h after all the test floors reached 30 °C. This relatively long heating period before mid-bake sampling probably accounts for the finding that most of the target VOCs and the aromatic portion of the TVOC measurement showed large decreases in concentration in the mid-bake sampling period. This suggests that the most volatile compounds were driven off before the mid-bake sampling took place. Future bake-out studies might include continuous VOC monitoring before, during, and after the bake-out so an estimation of the volatilization rates during each critical phase of the study can be made.

Although floors 9 & 10 and 11 & 12 are on independent air handling systems, which are also separate from the rest of the building, some cross contamination from upper and lower floors by way of the elevator shafts was likely. As noted above, the building's elevators are staggered, and the upper set serves only floors 11 - 21. Cross contamination from upper floors still under construction may help explain why floors 11 & 12 typically had higher contaminant concentrations than the lower floors during this study. Another explanation of the higher contaminant levels on the upper floors, and the more dramatic reductions achieved there, could involve the application of solvent-laden building materials just prior to pre-bake testing. If significant construction activities took place on the upper floors before pre-bake testing began, one would expect initial pollutant concentrations to be higher, and the compound reductions achieved greater, simply because of higher starting concentrations. Unfortunately, records of the construction activities prior to bake-out are incomplete, and, because of the day-to-day variability of the work practices observed during construction, would likely be of little help in resolving this matter, even if they were available.

Previous bake-out studies[6] have shown more modest reductions (20 - 30%) in individual target VOCs, but similar reductions in TVOC levels. The large reduction in individual VOCs noted in this study (Tables IV - VII) (particularly toluene, xylene isomers, ethylbenzene) might be related to the high initial pollutant concentrations and the brief period of time between final construction activities and the start of the pre-bake sample period. Few (if any) bake-out studies have indicated initial pollutant levels as high as some of those noted in the present study (Table VIII). Comparably elevated pollutant concentrations inside recently completed buildings have been reported, however. Sheldon et al.,[3] in an investigation that included recently completed office buildings (monitored within one month of construction), reported elevated levels of some of the same compounds identified in the present study: straight chain aliphatic hydrocarbons (n-decane, n-undecane, n-dodecane) and aromatic hydrocarbons (xylene isomers, ethylbenzene, ethyltoluene isomers, and trimethylbenzene isomers). Indoor concentrations of these compounds generally ranged between 10 and 400 $\mu g/m^3$ one month after construction. Interestingly, several months later, without any bake-out, the concentrations of these compounds generally ranged between 3 and 30 $\mu g/m^3$. Additional studies which compare the natural rate of contaminant depletion with the accelerated rate of depletion resulting from bake-out should help to further characterize the effectiveness of the bake-out process.

CONCLUSIONS

This bake-out study shows reductions in TVOC and individual targeted VOC source strengths as great as, or greater than similar recent studies. Although some compounds increased in concentration during the mid-bake phase, this study did not demonstrate a large increase in target compound concentrations during the building bake-out. The long period of sustained heating before mid-bake measurements were made ($\approx$ 60 h) probably allowed the concentrations of the most volatile VOCs to be reduced before the mid-bake samples were taken. Post-bake sampling shows that TVOC source strengths were reduced from 45 to 76% of their pre-bake levels. Differences in initial contaminant concentrations in the two air handling zones make it difficult to determine if lengthened heating periods correspond with increased reductions in contaminant levels. Many targeted VOC were reduced from 45 to 95% as a result of the bake-out. Although the most abundant aldehyde species concentrations increased approximately 65% during the mid-bake monitoring period, post-bake aldehyde concentrations remained similar to pre-bake levels. We conclude that a partial building bake-out, conducted on only a few floors of a new high-rise office building, can be an effective technique in the reducing human exposure to potentially irritating VOCs.

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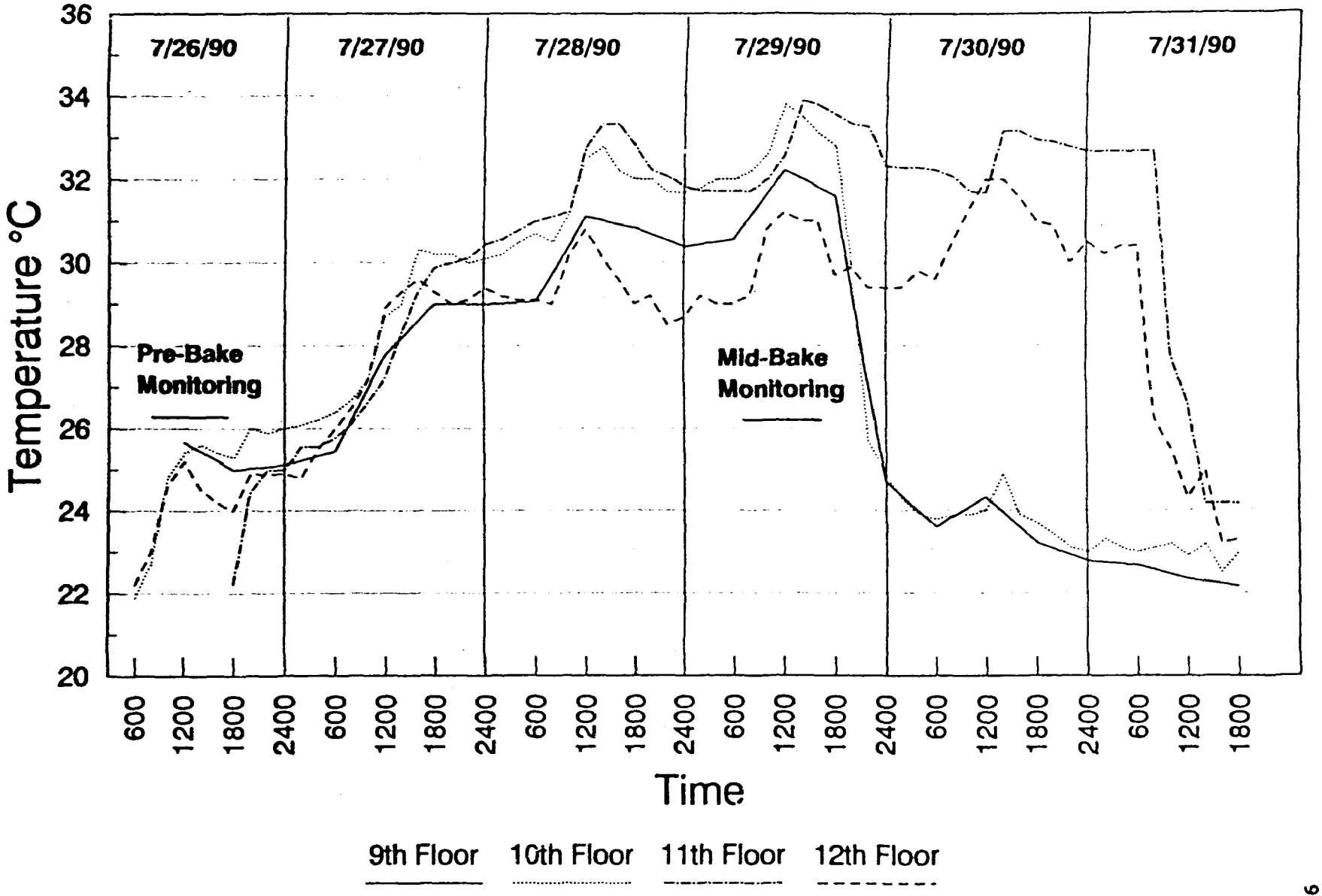

Figure 1. Region IX Bake-out Temperature Profiles

TABLE I. Sample collection schedule.

Floor & *Date	INTEGRATED VOC	GRAB VOC	CARBONYL	AIR EXCHANGE RATE
12th Floor	7/26	7/26	7/26	7/26
	7/29	---	7/29	---
	8/03	8/03	8/03	8/03
11th Floor	7/26	7/26	7/26	7/26
	7/29	---	7/29	---
	8/03	8/03	8/03	8/03
10th Floor	7/26	7/26	7/26	7/26
	7/29	---	7/29	---
	8/03	8/03	8/03	8/03
9th Floor	7/26	---	7/26	7/26
	---	---	---	---
	8/03	8/03	8/03	8/03
Roof	7/26	7/26	7/26	---
	---	---	---	---
	8/03	8/03	8/03	---

* 7/26 = Pre-bake, 7/29 = Mid-bake, 8/03 = Post-bake
--- = Not Measured

TABLE II. Average air change rates

FLOOR	PRE-BAKE (7/26/90)	MID-BAKE (7/29/90)	POST-BAKE (8/03/90)
12	1.11	0.63	1.26
11	1.20	--	1.21
10	0.81	--	0.84
9	0.74	--	0.90

* Measured air exchange rate under identical conditions (i.e., fresh air intake fully blocked) made on 11/01/90.

-- = Not Measured

TABLE III. Performance evaluation samples ($\mu g/m^3$).

COMPOUND	SPIKE 106 NOMINAL	SPIKE 106 REPORTED	SPIKE 106 % BIAS	SPIKE 089 NOMINAL	SPIKE 089 REPORTED	SPIKE 089 % BIAS	BLANK 004 REPORTED
Vinyl Chloride	8.8	0.8	90.9	6.2	0.6	90.3	ND
Vinylidene Chloride	13.6	13.9	-2.1	9.6	10.3	- 7.2	ND
Methylene Chloride	23.9	23.2	2.7	17.2	15.9	7.5	ND
1,1-Dichloroethane	14.7	12.9	12.3	10.6	9.2	12.4	ND
Chloroform	16.8	15.7	6.3	11.8	11.8	0.0	ND
1,1,1-Trichloroethane	18.7	16.7	10.9	13.2	12.6	4.8	ND
Carbon Tetrachloride	20.3	20.8	-2.4	16.1	15.7	2.5	ND
Benzene	22.3	20.5	7.9	16.2	15.0	7.0	ND
Toluene	13.7	12.6	8.0	9.9	9.3	6.0	T
Tetrachloroethylene	24.7	22.2	9.9	17.8	16.0	10.1	ND
1,2-Dibromoethane	27.9	25.4	9.1	20.2	18.0	10.8	ND
Chlorobenzene	33.5	30.8	8.0	23.7	23.3	1.8	ND
Ethylbenzene	32.5	29.7	8.5	23.3	22.0	5.4	ND
o-Xylene	36.9	27.8	24.6	26.3	21.1	19.8	ND
Styrene	15.1	ND	98.6	10.8	ND	99.0	ND

T = Trace
ND = Not Detected

TABLE IV. Selected VOC source strengths ($\mu g/m^2$ h) from integrated samples on the 12th floor.

COMPOUND	PRE-BAKE	POST-BAKE	% REDUCTION* PRE TO POST
Formaldehyde	98.4	99.1	-0.6
Acetaldehyde	23.0	22.7	1.3
Acetone	49.6	52.0	-4.8
Hexanaldehyde	10.4	8.9	13.9
1,1,1-Trichloroethane	44.8	57.5	-28.4
Benzene	16.0	17.8	-10.8
Toluene	522.9	67.0	87.2
n-Octane	16.1	T	40.8
Ethylbenzene	229.4	12.0	94.8
m,p-Xylene	872.7	44.1	94.9
o-Xylene	295.5	16.6	94.4
1,3,5-Trimethylbenzene	27.3	7.0	74.4
n-Decane	56.3	NC	---
1,2,4-Trimethylbenzene	41.7	22.2	46.7
Aliphatic Portion	3153.4	1583.8	49.8
Aromatic Portion	5423.7	508.1	90.6
Total TVOC	8577.1	2091.9	75.6

* A negative value indicates an increase in source strength
T = Trace
NC = Not Calculated, Chromatographic Interference

TABLE V. Selected VOC source strengths ($\mu g/m^2$ h) from integrated samples on the 11th floor.

COMPOUND	PRE-BAKE	POST-BAKE	% REDUCTION* PRE TO POST
Formaldehyde	142.2	126.3	11.2
Acetaldehyde	27.0	24.8	8.2
Acetone	57.0	54.3	4.8
Hexanaldehyde	15.0	11.8	21.4
1,1,1-Trichloroethane	61.2	39.1	36.1
Benzene	19.2	16.3	15.2
Toluene	547.3	69.1	87.4
n-Octane	30.2	12.3	59.3
Ethylbenzene	218.7	12.5	94.3
m,p-Xylene	830.8	48.3	94.2
o-Xylene	273.2	16.8	93.8
1,3,5-Trimethylbenzene	25.3	ND	98.3
n-Decane	78.5	ND	93.0
1,2,4-Trimethylbenzene	44.0	25.4	42.4
Aliphatic Portion	2907.9	2184.8	24.9
Aromatic Portion	5270.9	536.3	89.8
Total TVOC	8178.8	2721.2	66.7

* A negative value indicates an increase in source strength
ND = Not Detected

TABLE VI. Selected VOC source strengths ($\mu g/m^2$ h) from integrated samples on the 10th floor.

COMPOUND	PRE-BAKE	POST-BAKE	% REDUCTION* PRE TO POST
Formaldehyde	111.5	103.4	7.3
Acetaldehyde	17.5	20.2	-15.4
Acetone	27.5	37.7	-36.9
Hexanaldehyde	14.4	12.7	11.4
1,1,1-Trichloroethane	14.8	12.5	15.5
Benzene	12.4	11.0	10.9
Toluene	46.2	44.7	3.1
n-Octane	47.5	T	90.8
Ethylbenzene	11.8	5.7	51.7
m,p-Xylene	46.2	20.6	55.3
o-Xylene	15.3	7.2	53.2
1,3,5-Trimethylbenzene	4.1	3.6	11.9
n-Decane	32.8	ND	88.4
1,2,4-Trimethylbenzene	13.6	11.9	12.9
Aliphatic Portion	2138.8	906.1	57.6
Aromatic Portion	408.9	277.6	32.1
Total TVOC	2547.8	1183.8	53.5

* A negative value indicates an increase in source strength
T = Trace
ND = Not Detected

TABLE VII. Selected VOC source strengths ($\mu g/m^2$ h) from integrated samples on the 9th floor.

COMPOUND	PRE-BAKE	POST-BAKE	% REDUCTION* PRE TO POST
Formaldehyde	114.0	103.3	9.4
Acetaldehyde	14.5	16.3	-12.9
Acetone	24.8	36.5	-46.9
Hexanaldehyde	13.7	10.3	24.6
1,1,1-Trichloroethane	1069.4	13.3	98.8
Benzene	9.9	12.3	-24.4
Toluene	46.3	47.6	-2.9
n-Octane	49.0	T	90.4
Ethylbenzene	12.3	6.8	44.8
m,p-Xylene	44.8	23.4	47.8
o-Xylene	14.6	8.6	41.4
1,3,5-Trimethylbenzene	4.2	3.9	6.0
n-Decane	32.6	T	38.6
1,2,4-Trimethylbenzene	12.5	12.6	-0.3
Aliphatic Portion	2053.6	1052.6	48.7
Aromatic Portion	403.2	307.3	23.8
Total TVOC	2456.8	1359.9	44.6

* A negative value indicates an increase in source strength
T = Trace

TABLE VIII. Selected VOC concentrations ($\mu g/m^3$) from integrated samples on the roof and the 11th floor.

COMPOUND	PRE-BAKE	MID-BAKE*	POST-BAKE	% REDUCTION PRE TO POST	ROOF PRE-BAKE	ROOF POST-BAKE
Formaldehyde	32.6	48.7	28.7	11.2	7.2	6.9
Acetaldehyde	6.2	11.1	5.6	8.2	11.1	8.0
Acetone	13.1	16.3	12.3	4.8	8.2	8.0
1,1,1-Trichloroethane	14.0	7.0	8.9	36.1	28.5	4.1
Benzene	4.4	1.6	3.7	15.2	3.1	2.5
Toluene	125.5	49.2	15.7	87.4	27.8	7.5
n-Octane	6.9	8.7	2.8	59.3	ND	T
Ethylbenzene	50.2	7.3	2.9	94.3	7.8	1.3
m,p-Xylene	190.6	30.6	11.0	94.2	31.3	4.9
o-Xylene	62.7	12.5	3.8	93.8	10.8	1.9
1,3,5-Trimethylbenzene	5.8	2.4	ND	98.3	1.9	T
n-Decane	18.0	39.1	ND	93.0	T	T
1,2,4-Trimethylbenzene	10.1	7.7	5.8	42.4	4.3	2.4
Aliphatic Portion	667.0	1097.0	497.0	24.9	324.0	181.0
Aromatic Portion	1209.0	309.0	122.0	89.8	231.0	55.0
Total TVOC	1876.0	1406.0	619.0	66.7	555.0	236.0

* Mid-bake air change rates not measured. Pre- and Post-Bake air change rate = 1.2.
ND = Not Detected
T = Trace

TABLE IX. Hydrocarbon concentrations from integrated samples ($\mu g/m^3$).*

COMPOUND or CLASS	FLOOR	PRE	MID	POST
Aliphatic	9	764	---	322
Aromatic	9	150	---	94
Total	9	914	---	416
Aliphatic	10	727	969	297
Aromatic	10	139	124	91
Total	10	866	1093	388
Aliphatic	11	667	1097	497
Aromatic	11	1209	309	122
Total	11	1876	1406	619
Aliphatic	12	782	797	346
Aromatic	12	1345	201	111
Total	12	2127	998	457
Aliphatic	Roof	324	---	181
Aromatic	Roof	231	---	55
Total	Roof	555	---	236

* Concentrations not adjusted for changes in air exchange rate