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Indoor Air Quality Update™

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An Office Building Bake-out: Methods and Analysis

Bake-outs have probably generated more talk and less study than any other important indoor air quality topic. However, we are slowly learning more facts about bake-outs. Major contributors to our understanding of bake-outs are John Girman and his colleagues at the State of California's Indoor Air Quality Program (Department of Health Services, Berkeley). They presented their second paper on a controlled building bake-out in June at the latest meeting of the Air & Waste Management Association, in Anaheim, California. The results are encouraging for those who wish to use the bake-out process, and the paper teaches some important lessons.

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The state program performed bake-outs on five buildings and documented the tests thoroughly. The purpose was (1) to determine whether a bake-out is a practical technique to reduce volatile organic compounds (VOC) and improve air quality in newly constructed buildings, and (2) to determine optimal methods and procedures for conducting bake-outs.

Girman is a responsible scientist who has focused much of his research on practical, useful indoor air quality issues. His work on bake-outs includes several papers not yet published. He has told *IAQU* that he believes bake-outs can be effective. Our respect for his opinion leads us to agree.

However, Girman is a cautious researcher. He sees the need for considerably more research on bake-outs before finalizing his opinion on the subject. Readers contemplating a bake-out might do well to contact Girman before proceeding. *IAQU* welcomes any letters or reports from readers concerning building bake-outs.

In this article, we describe:

- The building studied by Girman, et al.;
- Bake-out procedures;
- Sampling methods;
- Test results.

We then discuss the implications of Girman's report and draw conclusions based on the report and our own experience with bake-outs. Our thanks go to John Girman for allowing us to present his work.

The Building

The building has a floor area of 4,800 m^2 (52,000 ft^2) and is located just northeast of San Francisco Bay. Temperatures vary moderately through the year. Freezing rarely occurs. Most rainfall occurs only in the winter months.

The wood-framed building has a stucco exterior with a shed roof. Metal roofing is installed around the building perimeter, with flat built-up roofing in the center. The first floor is built on a concrete slab poured on grade. The second floor is built on a plywood subfloor. R-19 insulation is used with a 4-mil vapor barrier. All windows are double glazed.

The interior of the building consists of a foyer, a large reception area, large open office spaces, small enclosed offices, conference rooms, an employee break room with a small food preparation area, two supply rooms, and several classrooms. Glued-down carpet was installed in most nonutility building areas one month before the bake-out. The exception was a 74-m^2 conference room that was carpeted on the second day of the bake-out.

A penthouse above the second story contains the HVAC mechanical room and an access hallway that serves as a return-air plenum. An enclosure on the far side of the employee parking lot houses the boiler and a/c compressors; associated plumbing runs underneath the parking lot to the building. The variable-air-volume, terminal-reheat ventilation system uses a T-bar suspended ceiling as the air return from the conditioned area.

Bake-out Procedures

A bake-out is controlled by adjusting three parameters:

- duration of the bake-out;
- indoor air temperature during the bake-out;
- ventilation rate during and after the bake-out.

Duration

From an engineering perspective, the duration of a bake-out should be as long as possible. In a sense, baking out is simply artificially aging the building. The more conditioned the materials, the less VOC are emitted. However, the cost of keeping a building empty usually dictates a short bake-out period. Also, construction and interior furnishing often run behind schedule, pressuring the builder to get the building operational quickly.

This bake-out lasted 3½ days. Figure 1 shows temperature profiles collected from three locations during the study. Notice that it took several days for air temperatures to reach 38°C (100°F), the desired maximum temperature.

Temperature

Elevated temperatures speed VOC emission in several ways. Heat raises vaporization rates; VOC evaporate significantly faster at higher temperatures. Residual solvents diffuse toward material surface areas quicker. Researchers elevated indoor temperatures with lighting (both artificial and natural), boiler modification, and portable heat sources.

All building lights were on during the bake-out period. Although individual fluorescent lights do not produce a lot of heat, the cumulative effect is significant. Also, the researchers opened and closed venetian blinds to take advantage of any possible greenhouse effect. They modified the boiler by installing a higher temperature control and disconnected thermostats throughout the building so that heaters would stay on regardless of outside temperature. Twenty space heaters (1,500 watts each) placed throughout the building contributed about 13% of the building's heat and enhanced indoor air circulation with their built-in fans.

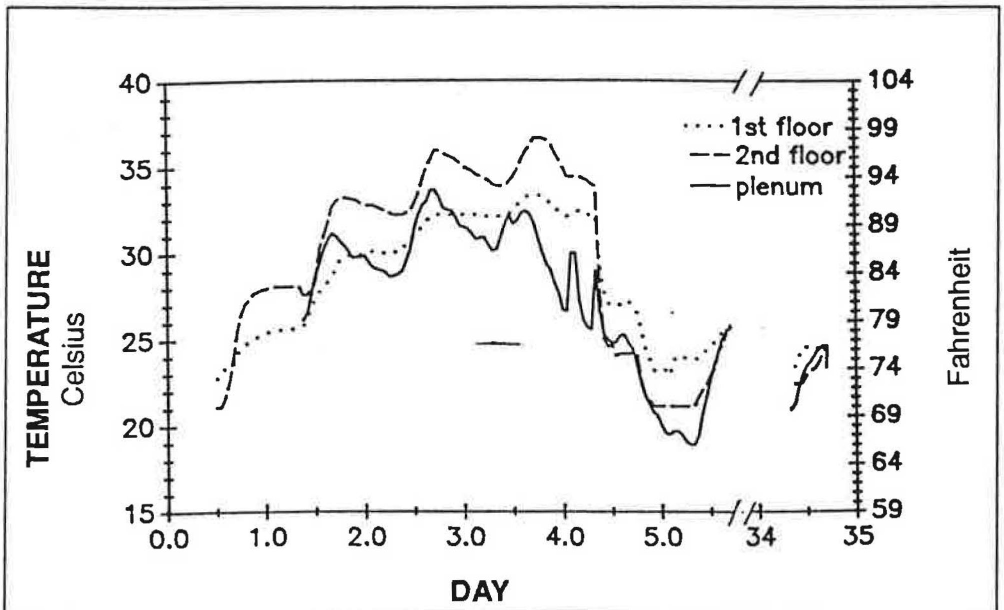

Figure 1 — Temperature Profiles Collected from Three Locations

month levels. The VOC reduction was permanent and had taken place within the month during and after the bake-out.

Building Materials

Effects of the bake-out on building structures and materials were minimal. Minor damages were limited to floors and doors. Of 18 expansion joints in the concrete slab, five moved inward. In four cases, carpet buckled slightly. A casual observer would probably think the buckling was a carpet seam. The carpet was not replaced or re-installed. In one case, vinyl flooring buckled in a supply room. Because the vinyl had less "give" than the carpet, the buckling was pronounced. Damaged sections of the vinyl were replaced.

However, the bake-out was probably not directly responsible for the buckling. The slab had been poured during a cold week in December, was wetter than normal, and was rained on during curing. The bake-out probably just accelerated the movement of the slab.

Of 225 double-glazed windows, one developed a crack starting at a screw closure. The builder felt the window was defective and replaced it without cost.

Interior doors had been propped open to facilitate air circulation

Table 1 — 19 Specific VOC Concentrations

CONCENTRATIONS ($\mu g/m^3$)

	Pre-Bake-out				Post-Bake-out			
	First Floor	Second Floor	Plenum	Roof (Outdoor)	First Floor	Second Floor	Plenum	Roof (Outdoor)
Formaldehyde	51	32	34	BD	65	40	38	BD
Methylcyclopentane	24	30	27	9.4	14	20	17	7.0
n-Octane	12	7.3	7.9	1.6	2.3	1.3	2.7	1.1
n-Undecane	16	14	17	6.6	13	15	14	5.5
n-Dodecane	9.0	3.7	7.8	0.6	2.5	1.7	1.0	BD
Benzene	2.8	3.0	3.0	1.0	0.8	1.5	BD	BD
Toluene	35	38	28	8.9	19	22	12.0	3.7
Ethylbenzene	7.5	7.6	7.3	3.0	6.1	7.1	6.1	2.6
i-Propylbenzene	11	11	11	4.8	9.2	11	10	4.0
m,p-Xylene	15	14	7.3	4.4	11	12	8.1	1.4
o-Xylene	7.7	7.7	7.3	2.8	5.7	6.4	5.4	1.0
1,4-Methylethylbenzene	7.4	3.8	7.0	2.8	5.0	5.9	2.2	1.1
1,2,3-Trimethylbenzene	6.6	5.3	6.6	2.3	4.3	5.1	4.4	0.9
1,2,4-Trimethylbenzene	8.6	6.7	8.2	3.3	5.1	5.9	5.1	1.0
Naphthalene	31	3.7	24	9.9	21	19	24	BD
a-Pinene	89	77	76	10	65	75	60	7.8
1,1,1-Trichloroethane	23	26	6.1	BD	BD	BD	BD	BD
Perchloroethylene	13	14	35	3.1	9.4	11	10	4.5
Dichlorobenzene	6.2	3.0	6.6	17	5.1	7.0	15	4.9

BD = below detection

during the bake-out. Spring closures at the top of the doors pulled on the doors while jams at the bottom of the doors held them open. The resulting torque, combined with the bake-out heat, warped some of the doors. These doors were straightened. In subsequent bake-outs of other buildings, researchers removed spring closures and warpage was eliminated.

Costs

The costs to the building owner for conducting the bake-out are listed in Table 2. Of the total cost, 59.5% went for contractors and operating engineers, 39.5% went for utilities, and 8% went for building damage.

Our Conclusions

Planning — Conditions vary greatly from one building to another; there is no "master plan" for bake-outs. Careful planning is a must before undertaking any bake-out program. However, unpredictable and/or uncontrollable conditions are the rule rather than the exception with these kinds of programs.

Anyone managing a bake-out must be flexible and ready to modify plans as required. A qualified individual capable of operating the building ventilation system should be on hand or on call during the bake-out process to deal with unexpected contingencies.

Duration — We think a week is the minimum time required to properly and safely conduct a bake-out. A bake-out of only a day is probably not enough to achieve any significant results. Effective bake-outs require several days and elevation of the building temperature above 90°F. The time allotted for a bake-out will depend on many factors, most having little to do with IAQ. Allow the most time possible.

Overheating — Do not overheat a building to the point where damage might occur. Overheating or elevating temperature too rapidly can cause drying and subsequent shrinkage of wood framing, excessive expansion of steel framing, and rapid drying of finishes such as newly applied paint.

Warranties — Be certain that the conduct of a bake-out will not violate manufacturers' warranties. Many building products and materials are warranted only under "normal conditions of use." A bake-out might be deemed a violation. If you are in doubt, contact the manufacturer or contractor who provided the warranty. This is particularly important for ventilation system components, millwork, art works, caulks, and sealants.

Ventilation — Maintain some ventilation during the bake-out period, but 0.4 or 0.5 ACH should be enough. After completing the bake-out and prior to re-occupancy, provide a purge cycle (100% outside air supply) for at least 24 hours. Thereafter, supply maximum feasible outside air.

Construction Activity — Frequently, some construction activity occurs up to the last minute before occupancy. The bake-out plan should take into account the likelihood that some workers will need access to the building, that elevated VOC levels might be created by the last minute construction, and that acceptable working conditions must be provided for any workers in the building during the bake-out.

Costs — The costs of a bake-out add up. It costs to heat the building, to operate the building's lights, to adjust or modify the HVAC system, and to monitor the building during the bake-out. However, these costs are small compared with the total building cost, and the rewards are significant: happier occupants, greater productivity, and less ill-

Table 2 — Costs Incurred for the Bake-out of a New Office Building

Item	Itemized Costs	Total Costs
Contractor		
General Contractor	$1,267	—
Mechanical Contractor	$1,750	—
		$ 3,017
Operating Engineers (monitoring building during bake-out)	$3,381	$ 3,381
Utility Costs		
Gas	$1,370	—
Electric	$3,449	—
		$ 4,819
Vinyl Floor Repair		$ 980
		$12, 197

ness due to indoor air contaminants.

For More Information

To learn more about this study, contact: John Girman, Indoor Air Quality Program, Calif. Dept. of Health Services, 2151 Berkeley Way, Berkeley, CA 94704; Phone: (415)540-3130.

John Girman, et al., "Bake-out of a New Office Building to Reduce Volatile Organic Concentrations," Paper 89-80.8. Presented at the 82nd Annual Meeting of the Air and Waste Management Association, in Anaheim. California, June 25-30, 1989. Available from Air and Waste Management Association, P.O. Box 2861, Pittsburgh, PA 15230; (412)232-3444.

California Office of the State Architect, "Building Closeout Procedure," California Department of General Services, Office of the State Architect, Sacramento, CA, 95814, 1984.

J. Girman, L. Alevantis, G. Kulasingam, M. Petreas and L. Webber, "Bake-out of an Office Building," *Proceedings of the 4th International Conference on Indoor Air Quality and Climate*, W. Berlin, Germany, 1:22 (1987). ♦

News and Analysis

ASHRAE to Publish Ventilation Standard

At its June meeting, the ASHRAE Board of Directors adopted the proposed Standard 62-1981R, Ventilation for Acceptable Indoor Air Quality. The standard is being typeset now and should be available in September.

The board made only minor changes in the version acted on at the January meeting in Chicago, and it has already instructed the committee to prepare an addendum to restore the prior version. For details of the standard, see *IAQU*, February 1989.

ASHRAE plans to broadly publicize the adoption and publication of the new standard. We hope that publicity will encourage architects, engineers, and interior designers to become familiar with the standard. Responsible professional practice to control indoor air quality means that design professionals should recommend compliance with the standard to their clients.

As of our publication deadline, cost information for copies of the standard was not available. For information and to order copies of the standard, contact: ASHRAE Publications, 1791 Tullie Circle NE, Atlanta, GA 30324, (404)636-8400. ♦

HVAC System Commissioning Guidelines

The staff at ASHRAE expects HVAC commissioning guidelines to be ready for distribution in four to six months. As we understand the contents of the guidelines, they will not differ significantly from the previously published Public Review Draft. We had hoped that the final guidelines would incorporate more detail than was in the draft. It could benefit by inclusion of some of the outstanding information presented by guideline committee members at the ASHRAE Winter Meeting in Chicago earlier this year. Readers interested in more detailed guidance on commissioning should obtain those papers or look for them in *ASHRAE Transactions*. Our article in the February 1989 *IAQU* gives a summary of the more useful papers.

For more information, contact ASHRAE Standards, 1791 Tullie Circle NE, Atlanta, GA 30324, (404)636-8400. ♦

CIAR Solicits Grant Applications

The Center for Indoor Air Research (CIAR) has announced the availability of funds to support indoor air quality research in three topical areas. The CIAR lists the following topics as research priorities:

1. Environmental tobacco smoke (ETS), including respirable particulate and vapor-phase components.
2. Chemical contaminants from all sources, organic and inorganic.
3. Biological agents, including aeroallergens and aeropathogens.

CIAR lists the following projects that it has already funded:

- The Role of Foliage Plants in Indoor Pollution Control.
- The Effects of Smoking Regulations and Building Ventilation on Indoor Air Quality and Employee Comfort and Health in Offices.
- The Pulmonary Effects of Environmental Tobacco Smoke Exposure on Asthmatic Subjects.
- Monograph on the Chemistry of Environmental Tobacco Smoke
- Comparison of a Personal and Area Monitor for the Measurement of Ambient Nicotine.

The last two projects were reported in *Environmental Science and Technology* recently (see *IAQU*, May and June 1989).