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Does a Total Energy Recovery System Provide a Healthier Indoor Environment?

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ABSTRACT

An investigation was undertaken to determine the effect of outside air ventilation rates and the use of a total energy recovery system (TERS) on ambient pollutant concentrations in occupied zones of a newly constructed, 27-story office building. Pollutant concentrations were measured on two occupied floors of the building and on the TERS in the supply air, the return air, the exhaust air, and the outside air. The pollutant contaminant concentrations were measured in the occupied-zone sampling sites under three ventilation conditions: (1) with the TERS off and at 5 cfm (2.4 L/s)/person, (2) with the TERS off and at 20 cfm (9.4 L/s)/person, and (3) with the TERS on and at 20 cfm (9.4 L/s)/person. Pollutants monitored were volatile organic compounds including formaldehyde, respirable-sized particles, nicotine, and carbon dioxide. The potential for pollutant transference by the TERS was investigated in both the building and in a TERS installed in a ducting chamber. Lower indoor pollutant concentrations were found with an outside air ventilation rate of 20 cfm (9.4 L/s)/person as compared to using 5 cfm (2.4 L/s)/person. No pollutant transference by the TERS was detected.

INTRODUCTION

Optimization of indoor air quality in conjunction with maximization of energy conservation should be primary goals of healthy building design. These goals, as well as the recommendation in *ASHRAE Standard 62-1989* for a minimum of 15 cfm (7.2 L/s)/person of outdoor air, have helped to spark the development of new technologies that will meet the standard and yet be more energy efficient. One such system, a rotating heat-wheel-type total energy recovery system (TERS) utilizing a patented molecular sieve desiccant coating, has been installed in both a laboratory ducting chamber and a newly constructed, 27-story office building.

The TERS allows facilities to economically flush the building with outside air supplies that meet or exceed the recommendations of *ASHRAE Standard 62-1989*. The TERS installed in the office building provides 52,000 scfm (24,500 L/s) of preconditioned outdoor air to conventional air-handling systems located throughout the building, utilizing the energy contained in the 31,200 scfm (14,700 L/s) air quantity exhausted from the bathrooms and janitor closets. Ninety percent of the total energy exhausted from the building is recovered. The molecular sieve desiccant coating on the TERS wheel is designed to prevent supply air contamination from cross-contamination with the exhaust air.

OBJECTIVES

There were two primary objectives to this investigation:

(1) to measure the effect of outside air ventilation rates and the use of the TERS on ambient pollutant concentrations and

(2) to examine the potential for pollutant transference by the TERS from the exhaust air to the supply air.

STUDY DESIGN

The first objective was met by measuring pollutant concentrations at two sites on two different floors of the office building under three different ventilation conditions: (1) 5 cfm (2.4 L/s)/person (*ASHRAE 69-1982* recommendation for offices that do not allow smoking) with the TERS not operating; (2) 20 cfm (9.4 L/s)/person (*ASHRAE 62-1989* recommendation for offices); and (3) 20 cfm (9.4 L/s)/person with the TERS operating. The exhaust air was maintained at 1,000 cfm/floor during all of the study. Tracer gas studies were conducted to confirm these conditions. No sampling was conducted for two days after each adjustment of the building ventilation system. Pollutant levels were determined for volatile organic compounds including formaldehyde, respirable-sized particles, nicotine, and carbon dioxide. These levels were compared with the outside pollutant concentrations at the building outside air intakes.

The building at the time of this investigation was not complete on the building interiors. The floors chosen to be included in this study were not under construction and were fully occupied by the same tenant. The tenant did not allow smoking in its areas, but construction workers were seen smoking in the building.

A TERS was installed in a specially designed ducting chamber in a research laboratory. This system was designed and operated to simulate actual conditions of the TERS in field use. The return air duct was spiked with various contaminants to observe the potential for transference from the return air to the supply air. The initial spiking compounds were sulfur hexafluoride (SF_6), carbon dioxide (CO_2), and xylene. The concentrations were monitored with a real-time photoacoustical gas monitor. The distribu-

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tion of the contaminants throughout the system was monitored by observing concentrations in the supply air, the return air, the exhaust air, and the outdoor air.

The potential for transference from the return air to the supply air was also investigated in the building TERS. Pollutant concentrations were monitored with the TERS operating at maximum rotation speed in the supply air, the exhaust air, the return air, and the outside air supply. The pollutants that were monitored were volatile organic compounds including formaldehyde, respirable-sized particles, ozone, sulfur dioxide, and nicotine.

SAMPLING AND ANALYSIS

Formaldehyde Formaldehyde concentrations were determined by using NIOSH method 3500 (NIOSH 1989). Air was drawn through a midget impinger containing 10 mL 1% sodium bisulfite solution at 1 L/min for one hour using a personal sampling pump. The formaldehyde concentration was determined calorimetrically using chromatropic acid solution.

Volatile Organic Compounds Volatile organic compounds were concentrated on a multisorbent tube containing two graphitized types of carbon black, carbon molecular sieve (EPA 1989), and glass beads. Collection was made by drawing air through the sorbent tube at 0.2 L/min for 50 minutes using a personal sampling pump. Analysis was by thermal desorption/gas chromatographic/mass spectrometry.

Nicotine Nicotine concentrations were determined using EPA method IP-2A (EPA 1989). Analysis was by alkali flame ionization detection/gas chromatography. Sorbent tube collection was conducted at 1 L/min for one hour using a personal sampling pump.

Respirable-sized Particles Respirable-sized particles were measured using NIOSH method 0600 (NIOSH 1989). Collection was made using a cyclone on tared filters with subsequent gravimetric determination. Collection on the tared filter was made at 1 L/min for two hours using a personal sampling pump.

Ozone Ozone was analyzed calorimetrically using NIOSH P&CAM method 58 (NIOSH 1985). Collection was made with a midget impinger containing potassium iodide at 1 L/min for one hour using a personal sampling pump.

Sulfur Dioxide Sulfur dioxide was sampled and analyzed using NIOSH P&CAM method 268 (NIOSH 1985). Collection was made on treated filters at 1 L/min for two hours. Analysis was by ion chromatography.

Carbon Dioxide and Xylene Carbon dioxide was measured by using a direct-reading photoacoustical gas monitor. The instrument was also used to directly measure xylene concentrations.

Tracer Gas Studies Sulfur hexafluoride was used as a tracer gas and was measured using a direct-reading photoacoustical gas monitor. In the office building, a known quantity of tracer gas was injected into the building return air supply. The distribution of sulfur hexafluoride was determined by monitoring the rise and decay of sulfur hexafluoride in the building on the two floors being investigated. The air change rate was then calculated.

DISCUSSION AND RESULTS

As expected, there were differences in contaminant concentration levels in the occupied zones of the building between operating the building at 5 cfm (2.4 L/s)/person and operating the building at 20 cfm (9.4 L/s)/person. No meaningful differences were seen in operating the building with the TERS operating at 20 cfm (9.4 L/s)/person and operating the building at 20 cfm (9.4 L/s)/person with the TERS not operating. This is graphically depicted in Figure 1, which shows the total ion chromatograms of the volatile organic compounds at Site 1 (one of the occupied-

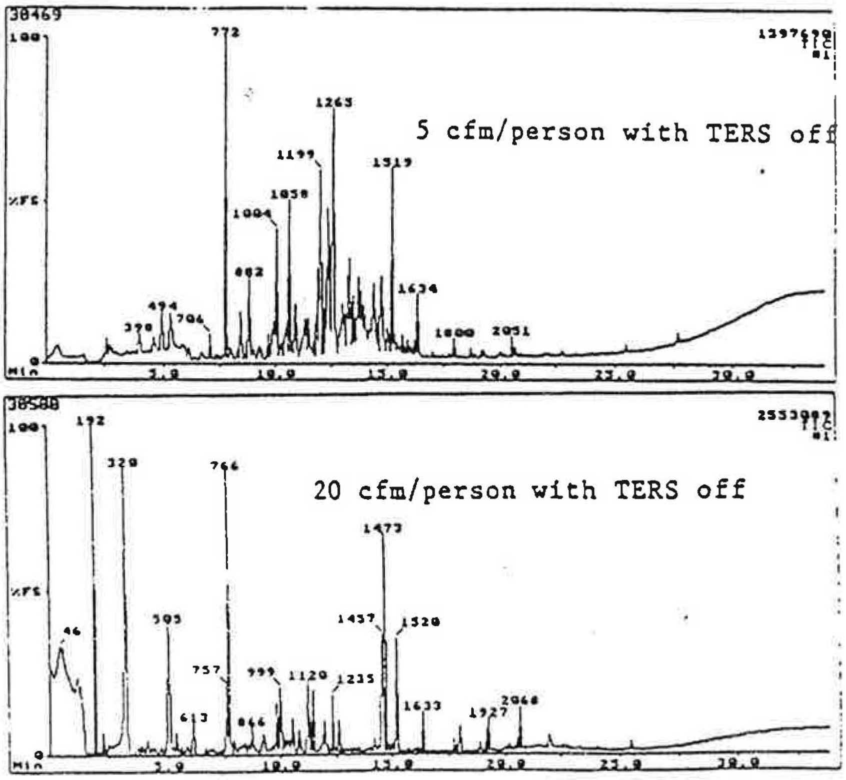

Figure 1 VOC reconstructed ion chromatograms of building at site 1

TABLE 1
Building Formaldehyde and Carbon Dioxide Concentrations at Each Ventilation Condition

VENTILATION CONDITION	CONCENTRATIONS: CARBON DIOXIDE PPM OA	3rd	6th	FORMALDEHYDE PPM OA	3rd Floor Site 1	Site 2	Site 3	6th Floor Site 4
5 cfm/person TERS off	390	925	1050	0.005	0.042	0.038	0.034	0.038
20 cfm/person TERS off	398	675	710	0.001	0.029	0.034	0.026	0.029
20 cfm/person TERS on	400	680	700	0.003	0.040	0.035	0.038	0.026

zone sampling sites). In Table 1, the formaldehyde and CO_2 concentrations at ventilation conditions 1, 2, and 3 are shown. In each of these it can be seen that the pollutant levels are lower when greater amounts of outdoor air are used to dilute and remove the pollutants from the occupied zones.

No pollutant transference was detected by the TERS in either the building system or the chamber system. As can been seen from the data presented in Tables 1, 2, and 3, no reintrainment of contaminants from the return air or the exhaust air of the tested contaminants is occurring.

TABLE 2
Formaldehyde Concentrations in TERS Sections

SAMPLING SITE	CONCENTRATION (PPM)
Outside Air 1	0.003
Outside Air Supply in TERS	0.003
Return Air	0.033
Supply Air	0.008
Exhaust Air	0.029

CONCLUSIONS

Differences in pollutant concentrations were observed at the *ASHRAE 62-1981* outdoor air ventilation rate of 5 cfm (2.4 L/s)/person. The exposure of the occupants to the indoor contaminants at this ventilation rate was higher than at the *ASHRAE 62-1989* outside air ventilation rate of 20 cfm (9.4 L/s)/person. As expected, no significant difference was noted on the indoor air pollutant concentrations with the TERS on or off while maintaining the ventilation rate at 20 cfm (9.4 L/s)/person. No pollutant transference was detected by the TERS from the return and exhaust air to the supply air in either the building or the ducting chamber experiments.

The importance of these findings is that the TERS has no detrimental effects on the quality of the indoor air. A healthier building with increased energy conservation can be achieved by using the TERS. The TERS allows for the operation of the building with increased outside air supply rates while reducing energy costs. A properly sized TERS could allow buildings to operate energy efficiently using 100% outside air to reduce indoor pollutant loads.

REFERENCES

EPA. 1989. Draft compendium of methods for the determination of air pollutants in indoor air. Contract Nos. 68-04-4467 and 68-02-4398. Washington, DC: Environmental Protection Agency.

NIOSH. 1985, 1989. *NIOSH manual of analytical methods*, 2d and 3d eds. NIOSH Publication No. 84-100.

TABLE 3
Xylene, SF6, and CO2 Concentrations in Sections of Laboratory Wheel

SAMPLING SITE	SF_6 TEST 1	SF_6 TEST 2	SF_6 TEST 3	CO_2 TEST 1	CO_2 TEST 2	CO_2 TEST 3	XYLENE TEST 1	XYLENE TEST 2	XYLENE TEST 3
Return Air	149	149	147	452	436	419	6800	7120	6900
Exhaust Air	122	133	145	455	431	403	5510	5770	5660
Outdoor Air	3.2	3.1	1.5	360	343	335	1790	1810	1810
Supply Air	1.7	2.5	0.72	346	340	340	1740	1800	1830

CONCENTRATIONS (PPM)