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HETA 86-045-1681
APRIL 1986
101 MARIETTA TOWER BUILDING
ATLANTA, GEORGIA

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I. SUMMARY

On November 13, 1985, the DHHS Region IV Employee Health and Safety Committee requested that investigators from the National Institute for Occupational Safety and Health (NIOSH) re-evaluate the air quality in the 101 Marietta Tower Building. A previous investigation in 1980-81 documented symptoms such as sinus congestion, eye irritation, and headaches throughout the building, affecting 30-40% of the sample population, but a causative agent could not be identified.

Six floors, the 2nd, 5th, 12th, 15th, 21st, and 30th, were selected for evaluation. The selection was based on previous occupant complaints and the desire to check floors from the upper and lower sections of the building. On November 19, 1985, NIOSH investigators started the requested evaluation. On the six floors selected for evaluation, NIOSH investigators inspected the interior of air-cooling and circulation units (air handling units), measured outside air supply volumes, and monitored the buildup of carbon dioxide.

Of the six floors tested, only the 2nd floor (based on the assigned occupancy load) received the amount of outside air ventilation (20 cubic feet per minute/person) recommended by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE). Outside air ventilation volumes for the other 5 floors were below the recommended rate, ranging from 10-17 CFM/person. Carbon dioxide (CO_2) buildup, used in this evaluation as an indirect indicator of indoor air pollution, exceeded the evaluation criteria of 1000 parts per million (ppm) on floors with higher occupancy loads. There was a significant ($p= < 0.05$) positive correlation ($r=0.85$) between peak CO_2 concentrations and the number of occupants working on a floor, and a significant ($p= < 0.05$) negative correlation ($r=-0.85$) between peak CO_2 concentrations and the amount (as CFM/person) of outside air ventilation supplied to each floor. Linear regression analyses of the 6 data points indicate that CO_2 buildup could be held below 1000 ppm if outside air ventilation for each floor of the building exceeded 19 CFM/person, or with current ventilation rates, where occupant loads are below 54 people per floor.

Based on our observations and measurement results, it has been determined that on floors with a high occupant density, not enough outside air ventilation was supplied to maintain a quality indoor air environment. Otherwise, air moving equipment inspected was found in good condition with cooling coils and condensation pans generally free of microbial slime. A detailed discussion of our investigation, findings, and recommendations is presented in this report.

KEYWORDS: SIC 9190 (Federal Governmental), indoor air quality, building-investigation, outside air ventilation, carbon dioxide

II. BACKGROUND

In 1980-81, NIOSH and the Center for Environmental Health, Centers for Disease Control, conducted a health hazard evaluation (TA 80-122-1117) requested by employees assigned to the Public Health Service (PHS) Region IV offices, located on the 10th, 11th, and 12th floors of the 101 Marietta Tower Building. PHS employees were experiencing eye and upper respiratory irritation, sinus congestion, mild headaches, and fatigue at work. The NIOSH survey documented widespread complaints of these symptoms throughout the building, affecting 30-40% of respondents to a questionnaire. Although extensive environmental sampling was conducted, the causative agents or conditions could not be identified. Recommendations were made for approaches to alleviate the problems; however, the cost of implementing the recommendations, the uncertainty of their effectiveness, and the lack of any outright violations of acceptable guidelines and standards for ventilation and indoor air quality prevented implementation of the recommendations.

The continuing incidence of employee symptoms and complaints, along with a report from the National Treasury Employees Union (NTEU), Chapter 210, that microbiological organisms had been identified in dust samples from the building, led the DHHS Employee Health and Safety Committee (composed of DHHS management and NTEU representatives) to request a re-evaluation of the building's air quality.

III. EVALUATION DESIGN AND METHODS

On November 19, 1985, NIOSH investigators met with representatives from DHHS management, NTEU Chapter 210, Balcor Property Management, the General Services Administration (GSA), and several interested DHHS employees to discuss the objectives of the building air quality evaluation.

Six floors, the 2nd, 5th, 12th, 15th, 21st, and 30th, were selected for evaluation. The selection was based on previous occupant complaints and the desire to check floors from the upper and lower sections of the building. On each floor selected, air circulation and cooling equipment, or air handling units (AHU), were inspected; the volume of outside air supplied to each AHU was measured; and, as an indirect determination of indoor air quality, the buildup of carbon dioxide (CO_2) was monitored.

A. AHU Inspection

To determine the potential for microbial contamination of the building, the two AHUs on each floor evaluated were internally inspected by removing access panels on the AHU to check the cooling coils and condensation pans for signs of microbial growth or condensate drainage problems. Samples of several small globs of wet or slimy material found in some of the AHUs were collected for possible identification by optical microscopy. However, NIOSH personnel experienced in conducting studies of microbially contaminated buildings, advised that further analysis of these samples would be of limited value to our investigation. Any deficiencies noted for AHUs were reported to the building maintenance supervisor who accompanied and assisted the NIOSH investigators during the survey.

B. Outside Air Supply Measurements

Since outside air delivered to an AHU is mixed with office return air inside the mechanical rooms, outside air rates were measured in each mechanical room (east and west) on all floors evaluated. This was done by measuring the velocity of the air discharged from the mechanical room's outside air supply duct. This procedure was used for the previous NIOSH investigation in 1981. However, to reduce the effect of turbulence from the outside air control damper, the NIOSH investigators on this evaluation measured airflow 18 inches down stream from the damper by placing an 18 inch cardboard extension over the end of the duct.

Nine airflow readings were taken over the face of the duct extension opening with a calibrated Kurzé Model 441 air velocity meter. The nine measurements were averaged and multiplied by the duct area (0.9895 square feet) to determine the volume of outside air supplied to each (east and west) mechanical room. The total amount of outside air for a particular floor was divided by the number of occupants assigned to that floor to determine the rate of outside air as cubic feet per minute per person (CFM/person).

An Alnoré Volometer Jr. was used to detect the direction of air flow out of or into the duct opening at each of the nine points. Inward flows were assigned negative velocities for computation purposes. In spite of the 18 inch duct extension, considerable turbulence was still present for some outside air ducts, as indicated by several inward flows detected near the bottom of the duct extension. Because turbulent flow is more difficult to accurately measure, there is a degree of uncertainty associated with these outdoor air supply measurements.

C. Carbon Dioxide Measurements

As an indicator of building ventilation effectiveness, the buildup of CO_2 was measured over the course of a workday on each of the six floors evaluated. CO_2 concentrations were monitored using direct reading detector tubes. These small glass tubes contained a chemical which turned purple in the presence of CO_2. To take a CO_2 measurement, the ends of the detector tube were broken open and attached to a hand operated pump. After a predetermined amount of air was pulled through the tube, the length of the color change inside the tube indicated the indoor air CO_2 concentration at that point in time. On each of the six floors evaluated, measurements were made 6 times on the east and west side of the floor at 8:30am, 10:30am, 12:30pm, 2:30pm, 3:30pm, and 4:30pm during the workday. Because of the number of measurements required, no more than two floors were tested on any given day. CO_2 testing was completed during December 1985.

The peak concentrations detected on the east and on the west ends of the floor, normally detected at about 3:30pm, were combined and averaged to determine the peak reading for each floor. Sign-in logs were checked to determine the exact number of people occupying the floor on the day of the testing. The previously measured outside air volumes for the floor were divided by the number of occupants working on the floor to determine the effect of outside air supply rates on indoor CO_2 levels.

IV. EVALUATION CRITERIA

The primary criteria used by NIOSH to evaluate the adequacy of the 101 Building's outside air ventilation systems is the Standard[1] recommended by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE), which specifies that building ventilation systems should supply at least 20 CFM of outside air per person in office spaces where smoking is permitted. Health complaints frequently reported by occupants of poorly ventilated buildings include headache, sinus congestion, eye irritation, and fatigue.

Other indicators of ventilation deficiency in a building include:

(1) an odor of cigarette smoke or general "staleness,"
(2) a marked temperature difference between areas owing to an HVAC system imbalance,
(3) closed supply or return air vents,
(4) supply and return vent locations which prevent movement of conditioned air to the breathing zone of occupants,
(5) closed outdoor air intakes, and
(6) elevated CO_2 levels.

CO_2 buildup in large buildings provides an easy-to-monitor index of building ventilation. The indoor CO_2 level is sensitive to both the level of human activity in a building and the ability of the heating, ventilation, and air-conditioning (HVAC) system to dilute the resulting indoor air contaminants.[2] Outdoor air contains a background of about 325 parts per million (ppm) CO_2. Building CO_2 levels below 600 ppm generally indicate adequate ventilation. Building ventilation should be considered inadequate when indoor CO_2 levels exceed 1000 ppm. In poorly ventilated buildings there will often be widespread occupant complaints because of a buildup of indoor air contaminants such as tobacco smoke, volatile organic compounds, and body odors.[2,3] A CO_2 level of 1000 ppm corresponds to the threshold suggested by both the World Health Organization and by the Japanese as a general indicator of the presence of indoor air pollution.[4,5] The 1000 ppm level is now under consideration by ASHRAE in their future revision of ASHRAE Standard 62-1981 which currently permits a maximum CO_2 concentration of 2500 ppm.

CO_2 buildup alone is not a health hazard in buildings unless concentrations are much higher. The OSHA Permissible Exposure Limit (PEL) for CO_2 is 5000 ppm and NIOSH has recommended an occupational exposure limit for CO_2 of 10,000 ppm. The 1000 ppm criterion for evaluating a building's indoor air quality is used herein as a surrogate for other indoor air contaminants which are not easily monitored or detected by conventional air sampling methods.

Ideally, CO_2 measurements should identify the peak concentrations that coincide with periods of peak occupancy and take into account the position of outside air supply dampers. Where a survey shows high CO_2 readings localized in certain areas of a building, rebalancing of the system may be sufficient to correct the problem. However, if elevated CO_2 readings occur throughout the building, an increased intake of outside air is indicated as an initial corrective action.

V. EVALUATION RESULTS

A. AHU Inspection

According to the building maintenance supervisor, the AHU coils and condensation pans were inspected and cleaned each year. However, the dates these inspections were performed had not been documented. Our general impression of the condition of the AHUs was favorable. Most of the AHUs inspected were clean inside with little slime or water accumulations in the condensation pans. Listed below are the findings noted during our AHU inspection and walk-through survey in the building mechanical rooms:

MECHANICAL ROOM	FINDINGS–COMMENTS
2nd floor-east	AHU slightly off level, 1/4 inch deep puddle of standing water in condensation pan not properly draining
2nd floor-west	Fan belt guard left unmounted on the AHU resulting in safety hazard for maintenance personnel from exposed rotating pulleys and drive belts.
5th floor-east	AHU air filter dirty–missed during previous scheduled replacement.
5th floor-west	AHU air filter dirty–missed during previous scheduled replacement.

MECHANICAL ROOM	DISCREPANCIES–COMMENTS
12th floor-east	No discrepancies noted
12th floor-west	Slight scum noted in AHU condensation pan
15th floor-east	No discrepancies noted
15th floor-west	AHU trough drain for external condensation blocked on back side of AHU
21st floor-east	Floating scum noted in condensation pan, air filter slightly dirty
21st floor-west	Air filter slightly dirty
30th floor-east	Outside air supply damper was found fully closed–a discrepancy noted and documented on our previous building study in 1981; thick chunks of slime and scum were found in AHU condensation pan
30th floor-west	AHU trough drain for external condensation blocked, small amount of slime found in condensation pan

B. Outside Air Supply Measurements

Air velocity readings for each of the outside air supply ducts tested are listed in Table 1. The negative values listed are where duct turbulence caused reverse flows at certain points along the face of the duct opening. The average air velocity from the outside air duct was multiplied by the area of the duct opening to determine the CFM supplied to the east and west mechanical rooms of the six floors evaluated. The total outside air supplied to each floor was divided by the floor's assigned occupancy rate to determine the outside air ventilation rate in CFM of outdoor air per person.

Based on the outside air volumes measured during this investigation, only the 2nd floor (21 CFM/person) met the ASHRAE Standard. The other floors had outside air volumes ranging from 10-17 CFM/person, with the lowest rates found on the 12th and 30th floors.

Obviously CFM/person outside air ventilation rates are directly affected by the number of persons occupying the floor served by the ventilation systems. If the rates of outside air measured by NIOSH during this investigation were held constant, the recommended 20 CFM/person would be provided if floor occupancy loads were lowered to the "Occupancy Limit" values listed in Table 1. For example, the 88 people currently assigned to the 12th floor receive 866 CFM of outside air or 10 CFM/person. However, if only 43 people occupied the 12th floor, then the current outside air ventilation of 866 CFM would provide the 20 CFM/person recommended by ASHRAE. To provide 20 CFM/person for the actual occupancy load on the 12th floor, outside air volumes should be increased to 1760 CFM. If, for example, occupant density on the 12th floor were increased from the current level to 105 assigned occupants, then the existing ventilation systems, as currently operated, would supply only 8 CFM of outside air per person. The above values for the other floors evaluated are shown in Table 1.

C. Carbon Dioxide Measurements

The peak indoor CO_2 concentrations detected on the 6 floors evaluated during this survey are listed in Table 2. Also listed are the number of people working on the floor when these CO_2 levels were monitored; the outside air volumes previously measured (see Table 1); and the CFM/person outside air rates for each floor, as determined by dividing the outside air volumes by the number of people working on the floor the day of the tests.

VI. DISCUSSION

Figure 1 shows a regression analysis of the data points obtained when comparing the peak CO_2 levels measured on 6 floors of the building to the actual CFM per person outside air rates. The negative correlation (r=-0.85) displayed in the graph was statistically significant
($p= < 0.05$). As displayed in the Figure 1, the data suggest that to hold CO_2 concentrations below 1000 ppm, the amount of outside air ventilation needed is near the 20 CFM/person criteria recommended by ASHRAE.

The above data suggest that the CO_2 buildup may also be dependent on the number of occupants as much as it is on the amount of outside air supplied. A similar regression analysis of the data shown in Table 2 is presented in Figure 2. As expected, the peak CO_2 levels did correlate (r=0.85) with the number of people working on the 6 floors tested ($p= < 0.05$). The data in Figure 2 suggest that with no modifications to the building ventilation systems, the current outside air volumes supplied to the building would maintain the recommended 1000 ppm CO_2 level for an occupancy load of only 54 people per floor.

The question arises why the outside air ventilation rates are now lower than when first measured by NIOSH in 1981. Our findings from that survey indicated the building met the requirements of ASHRAE Standard 62-1981. We believe the method used for testing the outside air supply volumes on this current investigation are more accurate than our previous tests because we used a duct extension to reduce the effect of turbulence from the outside air damper. In our 1981 report, NIOSH investigators recommended a 1050 CFM outside air supply minimum for each mechanical room. We also recommended that the building owner have the HVAC system tested and balanced. Had this been done, the actual outside air volumes could have been determined more accurately. However, because the NIOSH study found no indoor air contaminants or conditions in the building that could account for the reported health complaints and because the outside air ventilation rates appeared to meet the ASHRAE Standard, no further action was taken to test or modify the building's HVAC equipment.

Only within the last 2-3 years has NIOSH indirectly evaluated indoor air quality by measuring background CO_2 levels. Although NIOSH monitored CO_2 levels during the 1981 study, no 1000 ppm criterion had been suggested as a surrogate indicator of poor indoor air quality, and no effort was made in 1981 to measure peak CO_2 concentrations in the office work areas near the end of the workday.

Regarding microbial contamination, the 101 Marietta Tower building has to our knowledge had no recurring problems with flooding, roof leaks or plumbing leaks. There was no visible mold growth observed in the building and the AHU condensation pans inspected were generally free of microbial slime. A previous finding of bacteria and fungi in a dust sample taken from the building's return air plenum was not surprising. Bacteria and fungi occur naturally in the environment. The primary source of bacteria in the indoor environment is the human body. For example, about 7 million skin scales are shed every minute per person, and each fragment holds an average of 4 viable bacteria. Aspergilli are considered a most common group of indoor fungi.[6]

At present, there are no environmental criteria for assessing risk factors regarding the development of hypersensitivity lung illness, or allergies from exposures to airborne microbial contaminants. Furthermore, illness outbreaks cannot be determined by environmental studies alone. Typical symptoms associated with microbially contaminated buildings include fever, chills, muscle aches, chest tightness, and cough with onset generally 4 to 8 hours after exposure. Since health complaints by occupants of the 101 Marietta Tower Building have been mostly headache, eye irritation, and sinus congestion (symptoms associated with poorly ventilated buildings), further efforts to evaluate microbial levels and suspected associated illnesses would be of limited value.

VII. CONCLUSIONS

A dramatic increase in occupancy without HVAC adjustments can change an area from being properly ventilated to one uncomfortable, or even unhealthy.[7] Based on the results obtained from our testing of the outside air supply systems, and the level of CO_2 buildup on the floors evaluated, we have concluded that additional outside air ventilation is needed in the 101 Marietta Tower building to accommodate the existing occupancy load. The decrease in space allocation now mandated for all federal agencies to a level of 135 square feet per person is likely to have further detrimental effects on indoor air quality unless HVAC systems are modified to provide for the larger occupancy load.

VIII. RECOMMENDATIONS

1. The building HVAC systems should be improved through appropriate engineering changes to provide 20 CFM of outside air/person. The design should allow for the maximum anticipated floor occupancy loads expected for the mandated space consolidation now underway. Based on an occupancy load of 105 occupants per floor, the amount of outside air required would be about 1050 CFM/mechanical room, or 2100 CFM per floor.

2. Building HVAC systems should be capable of distributing outside air evenly through the occupied spaces of the building to maintain indoor CO_2 concentrations below 1000 ppm and thereby reduce the buildup of other indoor pollutants inside the building.

3. As an interim measure, managers should consider prohibiting smoking in offices where health complaints have been reported. In some office configurations, smoking bans may be appropriate for either the entire east or west section of a floor. In open office configurations, smoking restrictions may be required for an entire floor.

4. Air filters for the AHUs on the 5th floor were not changed within the prescribed interval. To help prevent these maintenance oversights, building maintenance personnel should maintain a log of scheduled preventive maintenance activities on all HVAC equipment.

5. AHU cooling coils and condensation collection systems should be cleaned and inspected each year. Chlorine generating slimicides and proprietary biocides may be used for disinfection if these chemicals are removed before AHUs are reactivated. Microbiocidal chemicals and corrosion inhibitors, such as those commonly used in cooling towers, should never be sprayed or applied within an operating HVAC system of an occupied building.

6. All unmounted fan belt guards should be re-installed on the AHUs to prevent accidental injury from possible contact with exposed rotating belts and pulleys.

7. If engineering changes to the HVAC equipment are not feasible, then the occupancy load on each floor could be limited to the extent that all occupants receive at least 20 CFM of outside air per person and indoor CO_2 buildup does not exceed 1000 ppm.

IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

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9. Balcor Property Management
10. U.S. Department of Labor, OSHA, Region IV
11. TEC/FAP, OSHA, Region IV
12. NIOSH Region IV
13. Designated State Agencies

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TABLE 1
OUTSIDE AIR VENTILATION MEASUREMENTS

101 MARIETTA TOWER BUILDING
ATLANTA, GEORGIA
HETA 86-045
November 1985

Location	2-west	2-east	5-west	5-east	12-west	12-east	15-west	15-east	21-west	21-east	30-west	30-east
Air Vel. (FPM)	1100	600	850	400	900	450	850	450	1050	850	900	0
"	900	350	550	-100	650	130	850	130	500	1050	750	0
"	1150	700	700	450	900	250	1000	450	950	1250	700	0
"	700	750	325	600	450	350	350	650	500	500	700	0
"	400	650	-120	150	-100	100	-60	100	-60	650	450	0
"	700	1000	400	700	350	400	290	300	200	1150	750	0
"	400	800	-350	1000	350	1050	300	1000	550	300	450	0
"	100	900	-100	800	-75	600	-60	750	-100	550	100	0
"	300	1000	-150	1000	170	950	160	700	200	950	400	0
Avg. Air Vel.	639	750	234	556	399	476	409	503	421	806	578	0
Duct Area	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
CFM O.A.	632	742	231	550	395	471	405	498	417	797	572	0
Total Outside Air	1374		781		866		903		1214		572	

	2nd Floor	5th Floor	12th Floor	15th Floor	21st Floor	30th Floor
Assigned Occupancy	65	60	88	85	71	60
CFM/person Outside Air	21	13	10	11	17	10
% of ASHRAE Std	106	65	49	53	85	48
Occupancy Limit	69	39	43	45	61	29
CFM O.A./ sq. ft.	0.09	0.05	0.05	0.06	0.08	0.03
O.A. if 105 people/floor (CFM/person)	13	7	8	9	12	5
Recommended Outside Air for Assigned Occupancy	1300	1200	1760	1700	1420	1200

FPM = Feet of Air Per Minute
CFM = Cubic Feet of Air Per Minute
O.A = Outside Air

TABLE 2

CARBON DIOXIDE MEASUREMENTS

101 MARIETTA TOWER BUILDING
ATLANTA, GEORGIA
HETA 86-045

November-December 1985

Floor Number	Carbon Dioxide (peak concentration)	Outside Air Rates (CFM)	Outside Air Rates (CFM/person)	People Working on Floor
2	800	1374	27	51
5	725	781	26	30
12	950	866	14.7	59
15	1400	903	14	65
21	850	1214	27.6	44
30	1300	572	7.2	80

CFM = Cubic Feet of air per Minute

FIGURE 1
CARBON DIOXIDE VS. OUTSIDE AIR RATE

101 MARIETTA TOWER BUILDING
ATLANTA, GEORGIA
HETA 86-045
November - December 1985

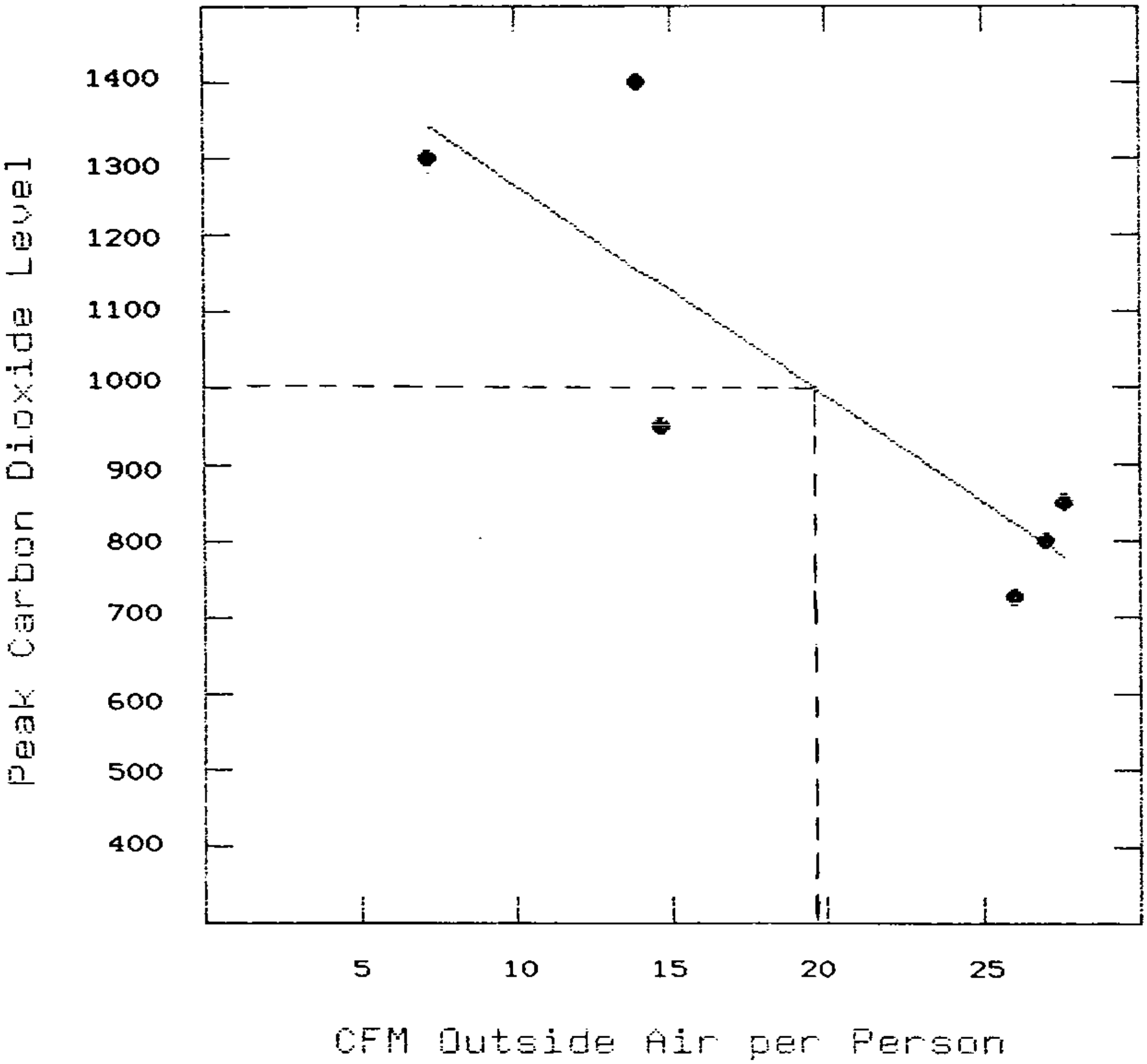

FIGURE 2
CARBON DIOXIDE VS. NUMBER OF OCCUPANTS ON FLOOR

101 MARIETTA TOWER BUILDING
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November - December 1985