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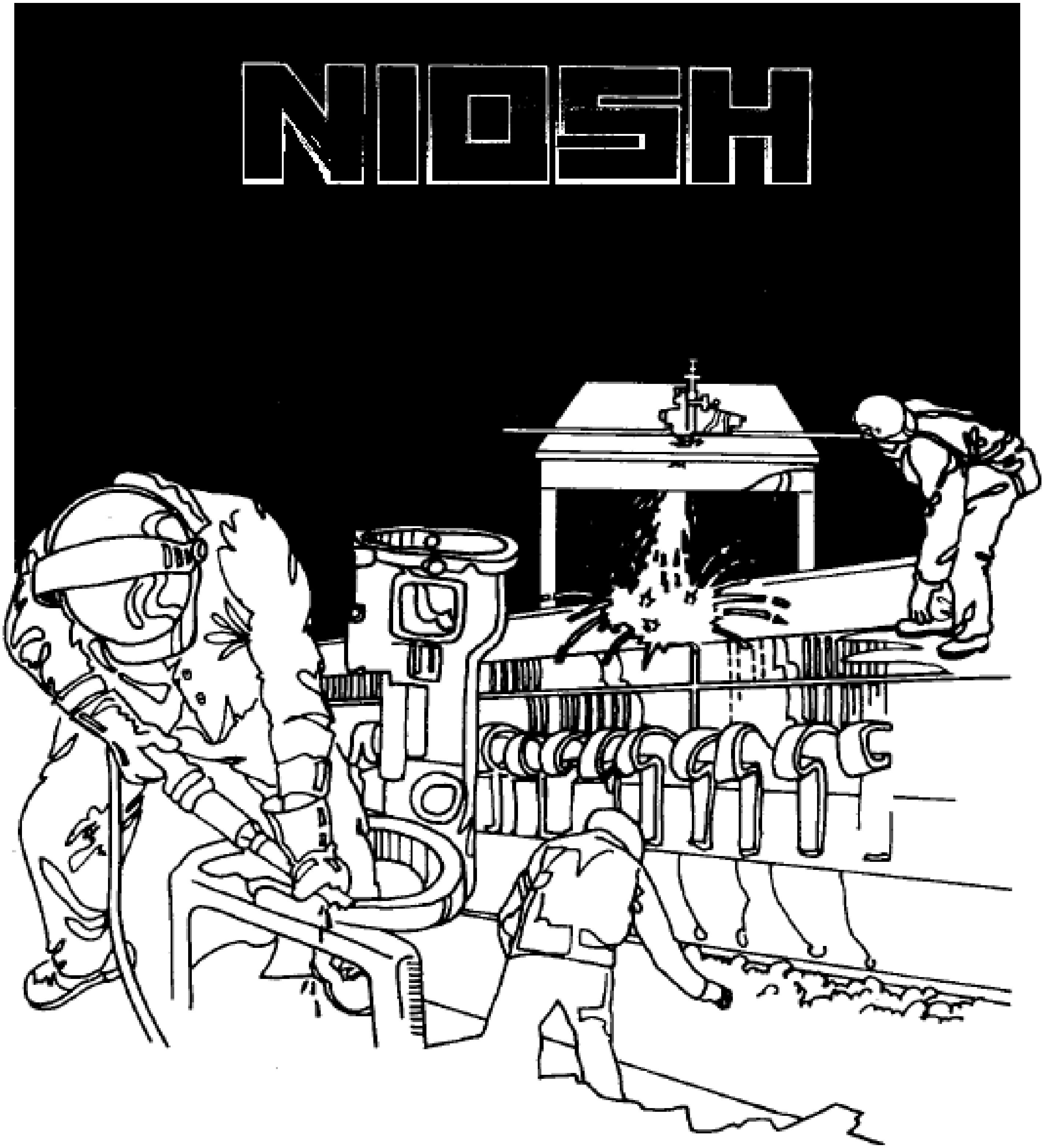

Health Hazard Evaluation Report

HETA 87-171-1840
NEW JERSEY DEPARTMENT OF TRANSPORTATION
TRENTON, NEW JERSEY

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

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NEW JERSEY DEPARTMENT OF TRANSPORTATION
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I. SUMMARY

On February 23, 1987 the Communication Workers of America (CWA), Local 1032 requested the National Institute for Occupational Safety and Health (NIOSH) to evaluate reports of skin rash, sore throat, headache, runny nose, watery eyes and inability to use contact lenses among employees in the Department of Transportation (DOT) Operations and Engineering building, Trenton, New Jersey. The reported symptoms were thought to be caused by formaldehyde from upholstered partitions, chairs and carpeted floors, and insufficient "fresh air." The request was assigned to the New Jersey State Department of Health (NJDOH) for follow-up under its Health Hazard Evaluation Cooperative Agreement with NIOSH.

NJDOH industrial hygienists performed air monitoring for formaldehyde, volatile organic compounds (VOC) and carbon dioxide (CO_2), carbon monoxide, ammonia (in a copy room), relative humidity and dry bulb temperature. The heating, ventilating, and air conditioning (HVAC) system was assessed; air velocity measurements were performed at the exhaust ports and inlet ports on the second and third floor at ceiling level with an Alnor Senior Velometer. The ventilation system in the smoking area was also studied.

The highest formaldehyde level found (0.094 ppm) approached the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommended level (0.097 ppm). CO_2 levels ranged from 400 to 1100 ppm; levels over 1000 ppm suggest inadequate fresh air. At three air handling units (AHUs), the volume of outdoor air ranged from 5-79 cfm/person; 20 cfm/person is recommended by ASHRAE. The higher levels of CO_2 and the lower volume of outdoor air are indicators of poor indoor air quality. Relative Humidity ranged from 28-34 percent; the NJDOH recommends levels of 40 to 60 percent.

A self-administered questionnaire was completed by 828 of approximately 1200 (69%) employees identified through the DOT's Personnel roster. The questionnaire was designed to determine the health status of the people working in the facility, the nature and extent of building-related complaints, and those areas within the facility that were most problematic from an environmental point of view.

Workers on floors 2 and 7 had more symptoms and complaints referable to the indoor environment. No epidemiologic association of health complaints with measured formaldehyde, volatile organic compounds (VOC) and carbon dioxide (CO_2), carbon monoxide, relative humidity and dry bulb temperature could be discerned from the questionnaire survey.

Based on the information obtained during this investigation several improvements are needed in the indoor air ventilation system to provide adequate quality and quantity of air in the NJDOT building. These problems and relevant recommendations are discussed in Section VI and VIII respectively.

KEYWORDS: SIC 9451 office building, indoor air pollution, carbon dioxide, temperature, humidity, formaldehyde

II. INTRODUCTION

On February 23, 1987 a representative from the Communication Workers of America (CWA), Local 1032 sent a request to the National Institute for Occupational Safety and Health (NIOSH) asking for an evaluation of reports of skin rashes, sore throats, headaches, runny noses, watery eyes and inability to use contact lenses among employees in the Department of Transportation Operations and Engineering Building at 1035 Parkway Avenue, Trenton, New Jersey. The reported symptoms were thought to be due to formaldehyde from upholstered partitions, chairs and carpeted floors, and insufficient "fresh air". The request was assigned to the New Jersey State Department of Health (NJDOH) for follow-up under its Health Hazard Evaluation cooperative agreement with NIOSH.

III. BACKGROUND

The Department of Transportation (DOT) employs approximately 1,200 people engaged mainly in engineering and office work in a new seven story Operations and Engineering Building. Employees began to occupy the building August 15, 1986. Simultaneously new furniture was brought in. The move was completed in November 1986. The complaints of eye irritation, sore throat and fatigue were first reported during the move.

Heating, Ventilating and Air Conditioning (HVAC) System

The two wings of this seven floor 'L' shaped building are designated as 'North Wing' and 'South Wing'. The North Wing and South Wing on each floor have separate air handling units (AHUs). The design of all AHUs is similar (Figure 1). The air is supplied through the AHU to the work areas of each wing via a Variable Air Volume (VAV) unit or box. Each VAV box is connected by ducts to a number of air inlet registers located on the false ceiling with a closed plenum. VAV boxes are provided with dampers. The movement of the dampers is controlled by thermostats located on the side walls which detect room temperature.

An enclosed duct is provided between the false ceiling and the true ceiling for the return air. The duct is provided with vent openings at various locations. These vent openings are expected to draw air from the exhaust port located on the false ceiling. There is no closed duct between the exhaust duct openings and the exhaust ports.

Heating is achieved by many decentralized heating units connected to air inlet plenums. Hot water is circulated in the periphery of the unit, and supply air is passed through the core of the unit. There is no centralized heating unit. Cooling is achieved by a centralized air cooling unit which is an integral part of each AHU. The outdoor air temperature, supply air temperature, return air temperature, total air volume, and other HVAC system parameters are recorded by a computer. Opening and closing of outdoor air dampers and recirculated air dampers is also controlled by the computer.

IV. METHODS

Environmental

On April 1, NJDOH industrial hygienists performed air monitoring for formaldehyde, carbon dioxide, carbon monoxide, ammonia (in a copy room), relative humidity and dry bulb temperature. Formaldehyde monitoring was performed over the full shift using NIOSH Method #3500.[1] The samples were analyzed in the NJDOH Environmental Laboratory by visible spectrophotometry. The approximate lower limit of detection was (0.03 ppm) at 77 to 83 liters air volume sampled. This sensitive formaldehyde monitoring method uses impingers and sodium bisulfite solution for the sampling. Carbon dioxide monitoring was performed with a Drager pump and colorimetric detector tubes. Carbon monoxide and ammonia monitoring was performed with an MSA pump and detector tubes. The minimum limits of detection for formaldehyde, carbon dioxide, carbon monoxide and ammonia were 0.03 ppm (at 77 to 83 liters of air volume sampled), 200 ppm, 10 ppm, and 5 ppm respectively. Relative humidity and dry bulb temperature were measured with a Serdex Humidity Temperature Indicator.

Measurements of formaldehyde, relative humidity, air concentration of carbon dioxide, and dry bulb temperature were made at fourteen areas throughout the building and included all seven floors.

On May 18, air monitoring was performed for carbon dioxide and volatile organic compounds (VOC). In order to achieve greater accuracy, the carbon dioxide monitoring was performed with a Miran Infrared Analyzer Model 1B. The minimum limits of detection for CO_2 (with the analyzer) and VOC (hydrocarbons) were 10.2 ppm and 0.08 ppm (with 10.5 liter air volume), respectively. The range of air volume sampled was 6 to 12 liters. CO_2 readings were taken with a Drager pump and detector tubes at the locations sampled by the Miran to identify the reason for the difference between the reading obtained from the Miran and those obtained from the detector tubes. VOC sampling was done on coconut shell charcoal tubes and analyzed by gas chromatography.[1] The samples were analyzed in the NJDOH Environmental Laboratory by gas chromatography. The specific compounds analyzed were aromatics, acetates, cyanide compounds, freons, hydrocarbons, ketones, chlorinated compounds, alcohols, ethers, and acrylates.

Air velocity measurements were performed at the exhaust ports and inlet ports on the second and third floors at ceiling level with an Alnor Senior Velometer.

The outdoor air volume, in cfm/person, for AHUs was determined using the outdoor air temperature, supplied air temperature, recirculated air temperature, and total air volume, taking into account the number of employees. The points where these temperatures were read are indicated in Figure 1. The data on the temperatures and the air volumes were obtained from computerized record sheets. These data and the sample calculation for outdoor air volume per person are given in Table 3.

The designated area for smoking and the ventilation system of the smoking areas was evaluated separately.

Medical

We utilized a self-administered questionnaire designed to determine the health status of the people working in the facility, their work history in the building, the nature and extent of building-related complaints, and those areas within the facility that were most problematic. The questionnaire was pretested using randomly selected employees at the NJDOH before administering it to the entire workforce. NJDOH investigators distributed the questionnaire to all of the DOT employees in small groups and collected them upon completion.

The questionnaire asked about 15 symptoms: chest tightness, cough, wheezing, dizziness, fatigue/drowsiness, eye irritation, headache, sneezing, sore throat, nasal/sinus congestion, nausea, nosebleed, skin irritation/itching, and leg pain, blood in urine. The questionnaire included questions pertaining to an employee's smoking habits and whether or not the respondent had seen a physician regarding any of the symptoms reported in the questionnaire. Employees were asked about their perceptions of aspects of their work environment: odors, air supply, humidity, dust on the furniture, dust in the air, cigarette odor, and noise.

Additional analyses of the questionnaires were performed in order to determine whether symptom or environmental complaint reports were related to location in the building (floor) or the measured environmental parameters.

In order to carry out these analyses, employees' questionnaire responses were categorized by 1) total number of symptoms of any kind, 2) total number of symptoms referable to the respiratory system, and 3) total number of environmental complaints.

V. EVALUATION CRITERIA

Environmental

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of agents to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH)[2] Threshold Limit Values (TLV's), 3) the U.S. Department of Labor (OSHA) occupational health standards,[3] and 4) the indoor air quality standards developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).[4] The first three sources provide environmental limits based on airborne concentrations of substances to which workers may be occupationally exposed in the workplace environment for 8 to 10 hours a day, 40 hours per week for a working lifetime without adverse health effects. The ASHRAE standards are general air quality standards for indoor environments, and are applicable for the general population exposed for up to a 24 hour day of continuous exposure without known toxic effects.

Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's are based usually on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH recommended exposure limits, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that New Jersey public employees are legally required to meet those levels specified under the Public Employees Occupational Safety and Health Act (PEOSHA). Under PEOSHA the federal OSHA standards were adopted. However, there are proposals to lower many of those standards based on the latest NIOSH and ACGIH recommendations. The proposed PEOSHA standards are published in the New Jersey Register, February 2, 1987.[5]

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8 - 10 hour workday. Some substances have recommended short-term exposures.

Indoor air should not contain concentrations of contaminants known to impair health, or to cause discomfort to a substantial majority of the occupants. Ambient air quality standards/guidelines available from federal, state, or local authorities should be consulted. If the air is thought to contain any other contaminants, reference to OSHA, ACGIH, and

NIOSH recommendations should be made; for application to the general population, the concentration of these contaminants should not exceed 1/10 of the limits which are used in industry.[4]

Several examples of common contaminants found in both industrial and non-industrial (indoor air) environments are shown below with their relevant environmental exposure criteria:

Contaminant	Allowable Concentration/Exposure Period: 8 Hour TWA (ppm)	Allowable Concentration/Exposure Period: Continuous	Source
Carbon monoxide (ppm)	50 (400C)	---	OSHA[3]/ACGIH[2]
	35 (200C)	---	NIOSH[6]
	---	9	ASHRAE[4]
	35		PEOSHA (proposed)[5]
Formaldehyde (ppm)	3	---	OSHA
	CA (0.1*)		NIOSH
	---	0.1	ASHRAE
	1**		PEOSHA (proposed)
Carbon dioxide (ppm)	5000	---	OSHA/ACGIH
	10,000	---	NIOSH
	5000		PEOSHA (proposed)

Note the difference between the CO_2 PEL's/REL's based on toxicity and the recommended guideline (1000 ppm) for evaluating indoor air quality.

NOTE: ppm = parts of contaminant (gas or vapor) per million parts of air, by volume.
CA = lowest feasible level (suspect or confirmed carcinogen), use best control technology.
C = short-term (15-30 min.) or ceiling limit.

* Revised May, 1986 as part of NIOSH testimony at OSHA hearing, represents the lowest reliable quantifiable concentration[7]

** Lowering the level to 0.1 ppm is under consideration

Formaldehyde is a colorless gas characterized by pungent and irritating odor. Acute toxic effects of formaldehyde include irritation of the eyes and respiratory tract, headaches, tiredness, dry cough, thirst and allergic contact dermatitis.[8] Formaldehyde is a cancer causing agent in animals.[9] There may be no safe levels of a carcinogen, so all contacts should be reduced to the lowest possible level.

Formaldehyde may cause an asthma-like allergy, with shortness of breath, wheezing, cough and/or chest tightness. Repeated exposure can cause bronchitis, with symptoms of cough and shortness of breath. Within the range of 0.1 to 3 ppm, most people experience irritation of the eyes, nose and throat.[10] In most healthy persons exposed to formaldehyde, concentrations greater than 5 ppm will cause cough and possibly a feeling of chest tightness.[10] In persons with bronchial asthma, the irritation caused by formaldehyde may precipitate an acute asthmatic attack, possibly at concentrations below 5 ppm.[10]

Neither NIOSH nor the Occupational Safety and Health Administration (OSHA) have developed ventilation criteria for general offices. Criteria often used by design engineers are the guidelines published by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). The latest draft of the ASHRAE-proposed Standard 62-1981[4] provides ventilation requirement guidelines for a wide variety of commercial, institutional, and industrial facilities, including office buildings. The standard states that indoor air quality for general offices shall be considered acceptable if the supply of outdoor air is sufficient to reduce CO_2 to less than 1000 ppm and contaminants such as various gases, vapors, microorganisms, smoke, and other particulate matter are controlled so that concentrations known to impair health or cause discomfort to occupants are not exceeded. The threshold levels for health effects from these exposures are, however, poorly documented.

For general offices the amount of outdoor air provided should be, at a minimum, 20 cfm/person. Non-smoking areas may be supplied at the lower rate of 5 cfm/person provided the air is not recirculated from, or otherwise enters from, the smoking areas.

Occupant discomfort results from build-up of numerous contaminants,[11] including cigarette smoke, hydrocarbons from copiers, etc., in the recirculated air within a building. The following evaluation criteria with regard to CO_2 in offices has been suggested by a Canadian investigator[12] and NIOSH[13].

CO_2 Level (ppm)	Comments
less than 600	Adequate outside air.
600-800	Occasional complaints, particularly if the air temperature rises.
800-1000	Complaints are more prevalent.
greater than 1000	Inadequate outdoor air in HVAC system; complaints are general.

Low relative humidity is undesirable because it will increase evaporation of moisture from the membranes of the nose and throat and cause drying of the skin and hair. Some medical opinion attributes the increased incidence of respiratory complaints to the drying out of mucous membranes due to low indoor humidity in winter.[14]

Studies of indoor areas show that temperatures greater than 78 F° and humidity less than 30 percent place employees in a "discomfort zone".[12]

The relative humidity range for minimizing as many adverse health effects as possible appears to lie between 40 to 60%.

Medical

Building-related illness episodes have been reported more frequently in recent years as buildings have been made more air-tight in order to conserve energy and to reduce air conditioning and heating expenses. Modern high-rise office buildings are constructed primarily of steel, glass, and concrete, with large windows that cannot be opened, thus making them totally dependent on mechanical systems for outdoor air. Contaminants may be present in make-up air or may be introduced from indoor activities, furnishings, building materials, surface coatings, and air handling systems and treatment components. Symptoms often reported are eye, nose, and throat irritation, headache, fatigue, and sinus congestion. Occasionally, upper respiratory irritation and skin rashes are reported. In some cases, the cause of the symptoms has been attributed to an airborne contaminant, such as formaldehyde, tobacco smoke, or insulation particles, but most commonly a single cause cannot be pinpointed.

VI. RESULTS AND DISCUSSION

Air Sampling

The results of the air monitoring are given in Tables 1 and 2.

Formaldehyde, carbon dioxide, relative humidity and dry bulb temperature monitoring was done at 14 locations in the building. One location, in each of the north and south wings of the seven floors, was sampled.

The highest formaldehyde level found (0.094 ppm) approached the ASHRAE recommended level (0.097 ppm).

The formaldehyde levels in all locations sampled were higher than outdoor formaldehyde levels in urban industrialized areas (0.003 to 0.005 ppm).[15].

Formaldehyde is released from particle board as well as some glues and adhesives commonly used in building construction. According to Cohen et al.[16], the average half-life of formaldehyde in a new mobile home is 4.5 years, meaning after 4.5 years the formaldehyde levels are expected to be half of the original levels.

The studies conducted by Anderson et al.[17], Myers[18], Godish et al.[19] suggest that an increase in indoor air temperature by 5 - 7 C°, results in the doubling of the formaldehyde levels. Conversely, a decrease in the temperature by 5 - 7 C° results in a reduction by one half the formaldehyde levels.

The April 1 monitoring for carbon dioxide using Drager detector tubes showed levels between 450 and 1100 ppm. CO_2 levels were found between 550 and 800 ppm in the air monitoring performed on May 18 with the Miran infrared analyzer, Model 1B, and by Drager detector tubes (Table 2). The analyzer was zeroed on the terrace of the DOT building just before the sampling. The CO_2 sampling was done with Drager detector tubes at the location where the analyzer was being zeroed. This level was added into the CO_2 results measured inside the building with the analyzer. The decrease in CO_2 between April 9 and May 18 could be due to an increase in the outdoor air volume recommended by NJDOH in a meeting held with DOT management and the CWA on April 22.

The upper limit guideline for CO_2 suggested by the Hazard Evaluation and Technical Assistance Branch of NIOSH for indoor air is 1,000 ppm. If CO_2 levels are below 600 ppm with comfortable temperature and humidity levels, complaints about air quality should be minimal. The CO_2 levels inside the building were approximately 2 to 6 times higher than the outdoor CO_2 level.

At all locations relative humidity levels were lower than the NJDOH recommended limit of 40 - 60%.

No detectable levels of VOC were found (the lower limit of detection is 0.08 ppm for total hydrocarbons) with 10.5 liters (range 6 to 12 liters) of air volume sampled.

The carbon monoxide level was below the lower detection limit of 10 ppm at a typical workstation. The sampling was done with an MSA pump and detector tube.

HVAC System

The levels of outdoor air ranged from 5 to 79 cfm/person on April 1 and from 21 to 120 cfm/person on May 18 (Table 3). The outdoor air volume measurements for AHU 1-1, 3-1, and 5-1, were lower than the ASHRAE recommended level of 20 cfm/person for office occupancy when smoking is allowed. As discussed later in this section, the exhaust from the smoking areas was located in the plenum so that cigarette smoke was recirculated into the HVAC system.

The percentage of outdoor air was determined on two dates (4/1 and 5/18) for 9 of the 11 AHUs. The percentage of outdoor air was lower on 4/1 (4%-54%) than on 5/18 (20%-66%) for the 7 AHUs, except for AHU 3-2 and 4- 7. This may be due to lower outdoor temperature of approximately 40°F on 4/1, and approximately 80°F on 5/18. In order to minimize heating of outdoor air to assure a comfortable temperature inside the building, more air may have been recirculated and less fresh air brought in on 4/1. According to HVAC maintenance personnel from DOT, 100% indoor air was recirculated in winter when the outdoor air temperature was very low.

The above data and elevated level of CO_2 are indications of poor indoor air quality in the DOT building on 4/1.

In Table 3 the temperatures marked with 'd' are questionable and were not used since they are not consistent with the majority of the data. For example, for AHU 6-2 the outdoor air temperature (obtained from a computer sheet) on April 1 was 64° F, and at the same time outdoor temperatures for other AHUs were in 40s. Similarly, for AHU 4-2, on April 1 when the outdoor air temperature was 44° F and recirculated air temperature was 71° F, the supply air temperature should have been lower than 71° F, instead it was 72° F. These data are an indicator of malfunctioning of some sensors in the computerized HVAC system.

There was no back-up system to periodically confirm the data read by the HVAC computer system. In order to identify whether the computer is reading actual data or to identify computer malfunctioning, the pitot traverse method can be used. This method requires the creation of holes in the main ventilation ducts which could be used for pitot traverses (a specialized air velocity measuring method) which measure air velocity inside a duct.[20]

The following design flaws were observed in the building's HVAC system:

1. The exhaust grills for the Air Handling Units (AHU) for floors #1, 2, and 3, north wing, are located near the air inlet grills of the AHU for the 4th floor, north wing. The air exhaust grills and the inlet grills of AHUs for all the other floors of the north wing and all the floors of the south wing are located side by side. This design may result in contamination of the fresh air intake by the exhaust air.

2. The air inlet registers and exhaust ports within the building are both located at the ceiling level. This design can result in poor air circulation at the working level in the room. At location 5407, the CO_2 level at the ceiling was lower than that at the work level. This is probably due to better delivery of fresh air at the ceiling level than at the work level.

3. The exhaust ducts located above the ceiling level are not directly connected with the exhaust ports located at the ceiling level. The amount of air exhausted through the exhaust ports would be greater if the exhaust ducts were connected to the exhaust ports. In addition, the exhaust duct inlet nearest to the exhaust ports will draw more air from these ports than from the exhaust ports located farther from the inlet, since the air will follow a path of the least resistance. This may cause uneven collection of the exhaust air.

It appears from DOT drawing #H-4 of the 2nd floor north wing (Figure 2), that the exhaust duct inlet located at the B-5-6 and D-3-4 areas may not be able to draw the air from the exhaust ports located in C-2-3, C-3-4, C-4-5, D-1-2, and D-2-3 areas. The third floor has the same arrangement. This appears to be the reason that we did not measure any air velocity with the Senior Alnor Velometer in the exhaust ports located in the above mentioned 2nd and 3rd floor areas.

Some of the exhaust ports were found completely blocked by waste insulation material; for example, the one near workstation 2302 was blocked with insulation.

Rest Rooms

No air movement was found in the 2nd and 4th floor men's rooms when tested with smoke tubes. It appears that the exhaust fan located on the terrace adjacent to these facilities is either not working efficiently, the capacity of the fan is not great enough, or the exhaust fan is not connected by duct work with the men's rooms.

Smoking

DOT has a written smoking policy dated September 1, 1986, that designates specific smoking areas. The conference rooms in the 2nd, 3rd, 5th and 6th floor training areas and a portion of cafeteria are the designated smoking areas.

The smoking rooms are provided with vents supplying and exhausting air. The supply and exhaust ducts terminated in the space between the false and true ceilings. Since this space is used as a plenum for the exhaust air in the HVAC system, the cigarette smoke is likely to be recirculated into the work area.

Medical

Of the approximately 1200 employees who were identified through the Department's Personnel roster, 828 completed the questionnaire, a participation rate of 69%.

The total number of symptoms reported per respondent is presented in Table 4A. The median number of symptoms reported per respondent was four. Approximately 25% of the respondents reported 6 or more symptoms and about 25% reported one or no symptoms. One hundred and fifty-nine respondents (19%) reported experiencing no symptoms. The maximum number of symptoms reported by one respondent was 15.

The number of environmental complaints reported per respondent is presented in Table 5A. Approximately 50% of the respondents reported 3 or more complaints. 78 respondents (9.4%) reported no environmental complaints. The maximum number of complaints reported by one respondent was 9.

The frequency distribution of each symptom for the 828 employees is shown in Table 4B. The most frequently reported symptom was fatigue and/or drowsiness with 438 employees (52.9%) reporting it. The second was sinus congestion, reported by 414 employees (50%).

The frequency distribution of each environmental complaint for the 828 employees is shown in Table 5B. The most frequently reported complaint was lack of air with 508 employees (61.4%) reporting it. The second was low humidity, reported by 390 employees (47.1%), and the third was high temperature, reported by 341 (41.2%).

Inter-floor analysis:

An analysis of both symptoms and environmental complaints was also made taking into account location of work by floor. In order to facilitate this analysis employees were categorized according to either 1) number of reported symptoms of any kind, 2) number of reported symptoms referable to the respiratory system, and 3) number of environmental complaints.

Tables 6A through 6C describe the prevalence of the general and respiratory symptom categories and environmental complaint categories by floor. In these analyses, floors 2 and 7 repeatedly showed a greater prevalence (higher percentage) of employees with both 3 or more symptoms and 3 or more complaints. There were no apparent environmental differences between these floors and the others.

Formaldehyde and air-quality analysis:

Results of the environmental measurements showed only moderate variation among locations with respect to the level of formaldehyde found. The average air concentration for all 12 samples was 0.054 ppm, with a range of 0.035 to 0.094 ppm.

The average concentration for the 12 samples for relative humidity was 31.4 with a range of 29 to 34; for CO_2, the average was 800 ppm, with a range of 475 to 1100; for dry bulb temperature, the average was 71.7, ranging from 67.5 to 74.

An analysis was also performed to determine if these environmental measurements were associated with either the general or respiratory symptom categories. People were first grouped by numbers of general or respiratory symptoms into 'low' and 'high' categories. Those in the 'low' group had fewer than 4 symptoms, those in the 'high' group had 4 or more symptoms.

Similarly, each person was then grouped by proximity to 'high' or 'low' levels of the four environmental parameters. This categorization process was based on the average measurement for each of the four parameters. For example, in the case of formaldehyde, the average formaldehyde level was 0.054 ppm. If a person worked in a location where the level was less than 0.054 ppm, then s/he was grouped in a 'low' formaldehyde area; correspondingly if a person worked in a location where the level was greater than 0.054, the person was grouped in a 'high' formaldehyde area. This same process was followed for the remaining three environmental parameters.

In all the analyses relating either general or respiratory symptom groups to the environmental parameters, no positive associations were detected (Tables 7A and 7B); that is, symptoms were not statistically related to higher levels of any of the four environmental parameters. Of particular interest, in the case of formaldehyde, the opposite was true; there were proportionally more people with symptoms in the 'low' formaldehyde areas than in the 'high' areas.

VII. CONCLUSIONS

The purpose of this investigation was to evaluate employee health complaints following a move into a new building and to attempt to identify the agent(s) responsible for the problem. We found that employees working on floors 2 and 7 had more symptoms and complaints than workers on other floors. There was no association, however, between symptoms and measured environmental parameters, including formaldehyde level.

Some temperature and humidity combinations were outside the comfort zone. Carbon dioxide levels and ventilation system measurements indicated inadequate fresh air.

VIII. RECOMMENDATIONS

1. Reduce levels of airborne formaldehyde as low as possible by optimizing building ventilation as suggested in recommendations 4 - 13 below, by increasing outdoor air volume, and by minimizing the indoor air temperature. As discussed in section VI of this report, minimizing the indoor air temperature may result in considerable reduction of the formaldehyde levels.

2. Locate the source of the formaldehyde by bulk sampling all suspected sources including carpeting, partitions, upholstery or other particle board or plywood sources. Once the sources are determined it can be decided whether it is feasible to remove them.

3. NJDOH is unable to recommend unconditionally the "bakeout" process to reduce formaldehyde levels until the efficiency of the building ventilation system is ensured. In the bakeout procedure, the air temperature in the unoccupied but fully furnished building is elevated while some ventilation is maintained to cause release and subsequent removal of formaldehyde and volatile organic vapors. There are possibilities that the formaldehyde liberated as a result of the "bakeout" may be recirculated or remain stagnant in some areas of the building. In addition, reliable data on the temperature and ventilation conditions to be maintained during, before and after "bakeout" are not available.

DOT may consider the possibility of performing an experimental bakeout. This would require prior determination of optimum capacity of the heating system to increase the temperature and the optimum capacity of the AHUs to provide outdoor air. Re-occupancy of the building after the bakeout should be allowed only after being certain that formaldehyde levels have decreased.

4. A comprehensive assessment of the building ventilation system should be performed, including the minimum outdoor air supplied (in cfm and percentage of total air) on each floor when the HVAC system is on. A pitot traverse of all main ducts should be performed periodically to ensure that the ducts are supplying/exhausting the air volume per the design capacity. Velocity measurements should be performed on exhaust ports to determine if there is even collection of the exhaust air.

5. DOT should ensure that at least 20 cfm/person of outdoor air is supplied at all times to all occupied areas, regardless of outdoor temperature.

6. Computerized reading of the temperature and air volume data and controls should be checked for their effective functioning, especially for AHUs 4-2, 5-1, 5-2, 6-2, and 7-2. Malfunctioning controls, if any, should be fixed.

7. In order to confirm the data provided by the computer, pressure drops in the HVAC system and air volume using the pitot traverse should be determined. Details on the diameter, number and spacing of the holes and the pitot tube method can be obtained from Reference 17.

8. Feasibility of providing a humidification system should be considered to ensure relative humidity of at least 40% in the heating season. In the cooling season relative humidity should be kept below 60%.

Humidifiers in HVAC systems should preferentially use steam as a moisture source. A dedicated "dry steam" system is preferable to systems that use raw steam from the central boiler system. The latter may contain corrosion inhibitors that are meant to carry over into condensate return lines. For steam humidifiers, avoid steam sources that contain volatile amines.

Humidifiers utilizing recirculated water are not recommended, as these can become rapidly contaminated with organic dust and microorganisms. Treatment of this type of humidifiers with biocides has been ineffective in controlling microbial contamination. If cold water type humidifiers are used, water should originate from a potable source and water, after passing through the humidifier, should be run into a drain line instead of being recirculated. The use of portable cold mist vaporizers is discouraged, since these devices are known to contaminate room air with microorganisms. The use of portable ultrasonic humidifiers may be effective in small areas.[21]

9. At least 40 cfm of air volume (as per DOT ventilation specifications) per urinal or toilet in the men's and women's toilet rooms should be ensured by either increasing the capacity of the exhaust fan drawing air from the toilet rooms and/or by assuring proper ducting from the fan to the rooms to minimize static pressure losses.

10. Exhaust fans from all the smoking rooms should be ducted outside the building to prevent recirculation of smoke-containing air in the building. Alternatively, the same type of ventilation system provided for the toilet rooms containing one exhaust fan drawing air from all the smoking rooms can be installed.

11. Feasibility of providing extension ducts or baffles to the outside exhaust grills of the AHUs for all floors should be considered to minimize the possibility of the exhaust air entering the intakes.

12. Provision of baffles in between the air exhaust ports and the air inlet registers and/or air inlet registers and exhaust ports in the periphery of the floors at the floor level should be considered to maximize circulation of incoming air throughout the room at work level.

13. Explore the possibility of providing a closed duct system connected from the exhaust plenums located between false and original ceilings to the exhaust ports and arrange to provide additional exhaust plenum openings in the areas not covered by the exhaust plenum as shown in Figure 2.

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Copies of this report are currently available, upon request, from NIOSH, Division of Technical Services, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through National Technical Information Service (NITS), Springfield, Virginia 22161.

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1. Department of Transportation, 1035 Parkway Ave, Trenton, NJ 08625

2. Communication Workers of America Local 1032 32 Scotch Road, Trenton, NJ 08628

3. NIOSH Region I, JFK Federal Bldg, Room 1401, Boston, MA 02203

For the purpose of informing the affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

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TABLE 1
AIR MONITORING RESULTS, DEPARTMENT OF TRANSPORTATION

Date of Sampling: April 1, 1987

Location Section	Formaldehyde ppm	Time	CO_2 ppm	Time	% relative humidity	Dry bulb temperature (°F)
1438	0.094[a]	10.04	-	-	34[b]	65[c]
		11.20	800[d]	15.30	34	70
		15.30	700	-	-	-
Mail Room	0.039	10.50	600	09.58	30	71
		15.40	600	15.40	29	70
Ladies Room	0.052	11.10	900	09.48	34	71
		16.05	900	16.05	31	71
2225	0.051	10.55	600	09.54	34	70
		15.50	800	15.50	31	71
3406	0.049	11.00	700	09.30	36	71
		16.15	600	16.15	30	71
3204	0.040	11.05	900	09.43	34	71
		16.25	800	16.30	30	71
4360 BEA	0.044	14.30	800	14.30	29	75
		17.30	400	17.30	30	72
4740 BEA	0.063	14.35	1000	14.35	30	74
		14.50	1100	-	-	-
		17.35	1000	17.35	30	71
5407 Design	0.035	14.10	1100	14.10	34	75
		14.20	700 (ceiling)	-	-	-
		17.20	900	17.20	30	72
5753 Bridge	0.045	14.05	500	14.05	31	74
		17.15	800	17.15	31	74
6737 Special Engineering	0.060	13.45	900	13.45	32	71
		17.00	700	17.00	30	73

TABLE 1 AIR MONITORING RESULTS, DEPARTMENT OF TRANSPORTATION (continued)

Location Section	Formaldehyde ppm	Time	CO_2 ppm	Time	% relative humidity	Dry bulb temperature °F
6404 Utilities	0.057	13.35 16.53	700 500	13.35 16.53	31 29	70 72
7404 Traffic	0.067	13.25 16.42	500 450	13.25 16.42	32 28	69 72
7748 Electrical	0.053	13.15 16.35	800 700	13.15 14.35	32 28	66 72
Outside	None Detected	10.35	200	10.35	55	50

* * *

a Formaldehyde concentrations in milligrams of formaldehyde per cubic meter of air
b Relative humidity in %
c Dry bulb temperature in F.
d Carbon dioxide concentrations in parts of carbon dioxide per million parts of air, determined by detector tube.

TABLE 2
CARBON DIOXIDE MONITORING WITH MIRAN INFRARED ANALYZER AND DRAGER DETECTOR TUBES, DEPARTMENT OF TRANSPORTATION

Date of Monitoring: May 18, 1987

Location	CARBON DIOXIDE LEVELS Miran Analyzer (ppm)	Detector Tube (ppm)	Time
1438*	-	800	15.40
2225*	-	600	15.22
3204*	-	800	15.00
5407	800	950	11.40
6737	650	900	11.20
7748	550	700	11.15
Outside		200	11.00

Note: DOT insisted NJDOH not perform CO_2 measurements on 4th floor as the AHU on 4th floor was reportedly under repair.

* * *

* Carbon dioxide sampling with the analyzer was not done at these locations because the battery of the analyzer was inoperative.

TABLE 3
DETERMINATION OF OUTDOOR AIR VOLUME PER PERSON
DEPARTMENT OF TRANSPORTATION

AHU#	To (F)		Tre (F)		Ts (F)		% outdoor air (%)		Supply air vol (cfm)		Outdoor air cfm/person	
Date	5/18	4/1	5/18	4/1	5/18	4/1	5/18	4/1	5/18	4/1	5/18	4/1
1-1[a]	86	45	71	73	77	45	40	7	16820	15620	58	8
2-1	87	44	72	74	76	69	27	17	-[b]	-	-	-
2-2	81	44	75	74	78	64	50	33	18020[c]	18020	120	79
3-1	90	47	73	71	78	70	30	4	14420	14420[c]	33	4
3-2	80	40	72	73	74	64	25	27	13700	14050	46	50
4-1	87	43	82	75	83	60	20	47	13700[c]	13700	21	49
4-2	83	44	72	71	79	72[d]	63	-	11100	-	94	-
5-1	81	38	77	77	84[d]	75	-	5	13700	13940	-	5
5-2	83	41	77	77	77[d]	72	-	14	16130	16130[c]	-	30
6-1	83	42	75	74	79	59	50	47	-	-	-	-
6-2	84	64[d]	79	74	81	72	40	20	-	-	-	-
7-1	84	44	75	74	81	64	66	33	14100	12480	71	32
7-2	82	42	76	75	75[d]	57	-	54	11620	10420	-	75

Nomenclature used in TABLE 3 and Sample Calculation for Outdoor Air

To - Temperature of outdoor air in F
Tre - Temperature of recirculated air in F
Ts - Temperature of supplied air in F (before heating/cooling device)

% of outdoor air = (Ts-Tre/To-Tre) X 100
- E.g. for AHU 1-1, 77-71/86-71 X 100 = 40%

Volume of outdoor
air per person = (% of outdoor air X Total air volume supplied)/(100 X Number of employees)
- E.g. for AHU 1-1, (40 X 16820/(100 X 130) = 52 cfm/person

* * *

a The first digit in the AHU number indicates floor number and the second, North or South wing. E.g. 3.1: 3rd floor/North wing; 4.2: 4th floor/ South wing.
b The blanks in the table are due to either the data not being available or because the calculations were not performed on the basis of questionable data.
c Air volume data assumed equal for the same AHU
d Data are questionable

TABLE 4A
FREQUENCY AND PERCENT DISTRIBUTION FOR NUMBER OF SYMPTOMS REPORTED PER RESPONDENT

No. Symptoms Reported Per Respondent	No.	%
0	159	19.20
1	74	8.94
2	91	10.99
3	82	9.90
4	96	11.59
5	57	6.88
6	77	9.30
7	65	7.85
8	40	4.83
9	35	4.23
10	22	2.66
11	12	1.45
12	12	1.45
13	2	0.24
14	3	0.36
15	1	0.12

TABLE 4B
FREQUENCY DISTRIBUTION OF SYMPTOMS FOR 828 EMPLOYEES WHO WORKED IN BUILDING

Reported Symptom	No.	%
fatigue and/or drowsiness	438	52.90
sinus congestion	414	50.00
eye irritation	376	45.41
headache	360	43.48
throat irritation	319	38.53
runny and/or itchy nose	281	33.94
sneezing	259	31.28
itchy skin	180	21.74
cough	179	21.62
dizziness	128	15.46
chest tightness	104	12.56
leg pain	84	10.14
wheezing	70	8.45
nose bleed(s)	56	6.76
nausea and vomiting	42	5.07

TABLE 5A
FREQUENCY AND PERCENT DISTRIBUTION FOR NUMBER OF ENVIRONMENTAL COMPLAINTS REPORTED PER RESPONDENT

No. Complaints Reported Per Respondent	No.	%
0	78	9.42
1	101	12.20
2	117	14.13
3	129	15.58
4	136	16.43
5	123	14.86
6	82	9.90
7	42	5.07
8	15	1.81
9	5	0.60

TABLE 5B
FREQUENCY DISTRIBUTION OF ENVIRONMENTAL COMPLAINTS

Environmental Complaint	No.	%
High humidity	70	8.4
Cigarette odor	94	11.4
Dust in the air	233	28.2
Other odor(s)	263	31.8
Dust on furniture	264	31.9
Low temperature	340	41.1
High temperature	341	41.2
Low humidity	390	47.1
Lack of air	508	61.4

TABLE 6A
NUMBER OF SYMPTOMS OF ANY KIND BY FLOOR

Floor	0-3 Symptoms	4 or more Symptoms
1	61 (65.59%)	32 (34.41%)
2	29 (43.28%)	38 (56.72%)
3	85 (44.50%)	106 (55.50%
4	62 (46.97%)	70 (53.03%)
5	77 (61.11%)	49 (38.89%)
6	59 (52.68%)	53 (47.32%)
7	33 (30.84%)	74 (69.16%)

TABLE 6B
NUMBER OF RESPIRATORY SYMPTOMS BY FLOOR

Floor	0-3 Symptoms	4 or more Symptoms
1	75 (80.65%)	18 (19.35%)
2	44 (65.67%)	23 (34.33%)
3	132 (69.11%)	59 (30.89%)
4	91 (68.94%)	41 (31.06%)
5	96 (76.19%)	30 (23.81%)
6	82 (73.21%)	30 (26.79%)
7	58 (54.21%)	49 (45.79%)

TABLE 6C
NUMBER OF ENVIRONMENTAL COMPLAINTS BY FLOOR

Floor	0-3 Complaints	4 or more Complaints
1	63 (67.74%)	30 (32.26%)
2	27 (40.30%)	40 (59.70%)
3	96 (50.26%)	95 (49.74%)
4	64 (48.48%)	68 (51.52%)
5	81 (64.29%)	45 (35.71%)
6	49 (43.75%)	63 (56.25%)
7	45 (42.06%)	62 (57.94%)

TABLE 7A
PROPORTIONS OF PEOPLE (PREVALENCE) WITH GENERAL SYMPTOMS

Environmental Category	Formaldehyde	CO_2	Relative Humidity	Dry Bulb Temperature
Low	63.2% (12/19)	65.2% (15/23)	50.0% (13/26)	57.14% (12/21)
High	44.8% (13/29)	40.0% (10/25)	54.5% (12/22)	48.15% (13/27)
P-Value (Chi Square test)	0.21	0.08	0.75	0.54

TABLE 7B
PROPORTIONS OF PEOPLE (PREVALENCE) WITH RESPIRATORY SYMPTOMS

Environmental Category	Formaldehyde	CO_2	Relative Humidity	Dry Bulb Temperature
Low	42.1% (8/19)	52.2% (12/23)	34.6% (9/26)	47.6% (10/21)
High	34.5% (10/29)	24.0% (6/25)	40.9% (9/22)	29.63% (8/27)
P-Value (Chi Square test)	0.6	0.04	0.65	0.20

Figure 1. SCHEMATIC OF AIR HANDLING UNIT
DEPARTMENT OF TRANSPORTATION

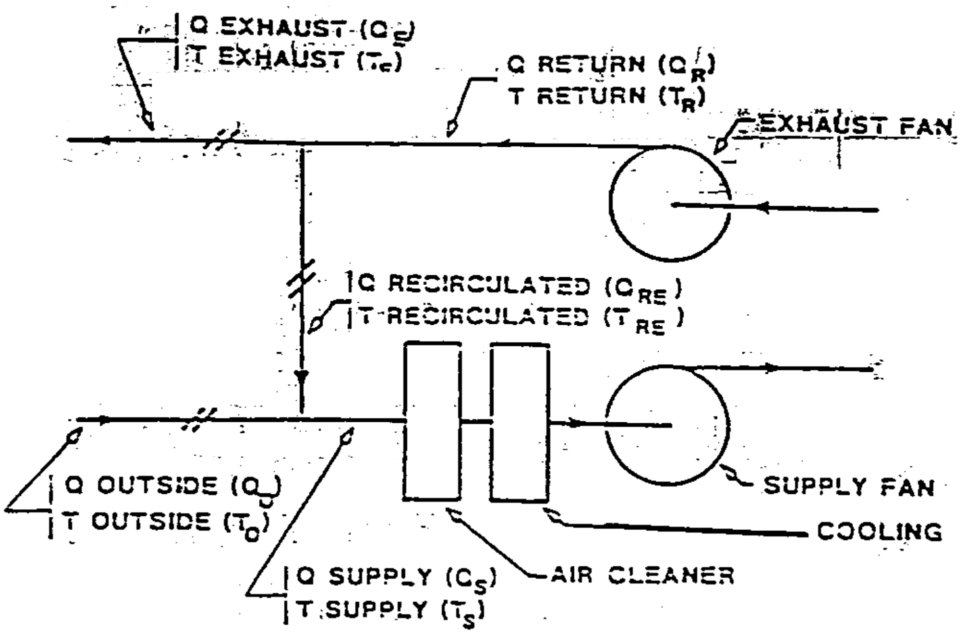

Figure 2. RETURN AIR DISTRIBUTION
DEPARTMENT OF TRANSPORTATION