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I. SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) received a request dated April 28, 1986, from the district office manager of the Social Security Administration, Philadelphia, Pennsylvania, concerning a variety of indoor air quality problems including intermittent odors resembling gasoline or kerosene, cigarette smoke, employee headache and nausea, and reports of "stale air". This office provides a variety of claims and beneficiary services to the public.

An initial industrial hygiene survey was conducted on August 13-14, 1986. Carbon dioxide (CO_2) concentrations ranged from 800 to 1000 parts per million (ppm) in the office areas (outside levels averaged 400 ppm). As inside CO_2 levels approach or exceed 1000 ppm, complaints such as headache, fatigue, and eye and throat irritation are common among workers and inadequate ventilation is suspected. Carbon monoxide (CO) levels were negligible (less than 5 ppm) and the temperature and relative humidity (RH) levels were within accepted comfort ranges. Informal interviews with 11 office workers indicated dissatisfaction with the ventilation system, including drafts (both hot and cold), temperature fluctuations, poor restroom ventilation, and a perceived lack of fresh air. No gasoline or kerosene odors were detected during the initial or follow-up surveys.

A follow-up visit was conducted on September 14-16, 1987, to more closely examine the three heating, ventilating, and air-conditioning (HVAC) systems supplying the office building. The CO_2 concentrations during this second visit ranged from 550 to 1200 ppm in the office areas (outside levels ranged from 350 to 450 ppm). CO levels were again negligible in all areas checked. Temperature and RH levels were generally within accepted comfort ranges, although some office areas were on the cold side of the ASHRAE comfort range.

Quantitative air flow measurements were made at all accessible air supplies and returns in the building using a mass flow hood. The air flow measurements indicated that the three HVAC systems were not balanced.

Based on these results, NIOSH has determined that inadequate ventilation exists within the Social Security District Office, Philadelphia, Pennsylvania. Recommendations to improve ventilation are included in Section IX of this report.

Key words: SIC 9441 (Administration of Social, Manpower, and Income Maintenance Programs), ventilation, indoor air quality, carbon dioxide, carbon monoxide, temperature, relative humidity.

II. INTRODUCTION

On May 8, 1986, NIOSH received a request for a Health Hazard Evaluation from the manager of the Social Security Administration's (SSA) District Office, Philadelphia, Pennsylvania. This office, which provides a variety of claims and beneficiary services to the public, is located in a single-story office building on the north side of the city. The request concerned employee complaints of "stale" air, headache, nausea, cigarette smoke, and intermittent odors resembling kerosene and gasoline. The kerosene and gasoline odors were suspected to originate from the periodic filling of underground storage tanks at a gasoline station adjacent to the office building.

An initial site visit was conducted by NIOSH investigators on August 13-14, 1986. Colorimetric detector tubes were used to measure carbon dioxide (CO_2) and carbon monoxide (CO) concentrations at various locations within and outside the building. Temperature and relative humidity levels were also measured. Eleven current employees were informally interviewed. The majority of those interviewed had noticed gasoline and/or kerosene odors, but only intermittently (once every one to two months), and among those interviewed, these odors were not a major concern.

A follow-up visit was performed on September 14-16, 1987, and CO_2, CO, temperature and relative humidity measurements, both within and outside the building, were again collected. In addition to colorimetric detector tubes, a portable infrared spectrophotometer was used to measure CO_2 both within and outside the office building. The three HVAC units were examined and quantitative air flow measurements made at all accessible air supplies and returns.

III. BACKGROUND

A. Building Description

The single-story brick office building, located in northeast Philadelphia, was constructed in 1969 and has been occupied solely by the Social Security Administration. The 10,000 square foot building is arranged in an "open office" concept (no interior dividing walls except for perimeter offices). The public entrance is on the east side of the building. There are offices and conference rooms situated along the entire south and west walls, and part of the east wall. One room is designated as a smoking area, but is also used as a lunch room and, intermittently, for employee training. Smoking is not permitted outside the lunch room. A diagram of the building is shown in Figure 1.

B. SSA District Office Smoking Policy

At the time of the initial site visit (August 13-14, 1986) a new smoking policy had recently been implemented which restricted smoking to designated areas of the building. Although this policy relocated smokers to specific sections of the central office area, the open design of this section (no walls) made control of the cigarette smoke difficult. Compounding the problem was the fact that the public was permitted to smoke in the waiting area located in the east end of the building (Figure 1).

During the follow-up visit the no smoking policy had been modified by further restricting employee smoking to a designated area (lunchroom) located on the perimeter of the building. The public was no longer permitted to smoke in the building.

C. Ventilation Systems

Heat is supplied to the building by three forced air furnaces which are part of the roof top air-conditioning units. Heat to the perimeter offices is supplemented by a gas-fired boiler which supplies hot water to perimeter convectors.

The three roof top forced air HVAC systems move heated and cooled air through the same ductwork. The building, for heating and air-conditioning purposes, is divided into three zones. Thermostatic controls for two of the three HVAC systems are accessible by employees if conditions become uncomfortable. The remaining HVAC system, supplying the perimeter offices, was intended to operate continuously (although NIOSH investigators observed the system being shut off by employees).

Tempered air is supplied to the building through louvered ceiling diffusers. The air is returned through plastic grilles also located in the ceiling. The ventilation schematic showing the location of the diffusers and grilles is presented in Figure 2.

The HVAC unit supplying all perimeter offices and meeting rooms is manufactured by ACME (Model RAC 15 DMZ). Air is supplied to the unit through either return or outside air dampers. These dampers modulate to control the mixed air temperature. From the dampers the mixed air passes through a filter bank and the fan. The fan pushes the air through the cooling coil or the heat exchanger (cold deck or hot deck) and into the four main system ducts. Dampers for each main duct control the amount of air coming from the cooling coil or heat exchanger into each zone's duct system. Room thermostats, shown in Figure 2, control the damper positions.
The other two air handling units are each single zone systems which service the open areas of the building (Figure 2). These areas include a public waiting area near the main entrance and a large general office area. One unit, manufactured by York (Model SS 242 G231-17C), services the western half of the building. For this unit, either outside or return air is supplied through dampers which modulate to control the mixed air temperature. After passing through the dampers, the mixed air passes through a filter bank, cooling coils and the fan before being pushed through a heat exchanger into the building. The second single zone unit, manufactured by Trane (Model SFHB 20006 HE 00F21BCO), provides ventilation for the eastern half of the office area and functions the same as the York unit.

Air not returned to the HVAC units exits the building through two paths. The first is the exhaust system for the restrooms, located in the southeast corner of the building. By design, the restrooms were supposed to have approximately 42% more exhaust than supply air. The second path is through leaks in the building structure and through doors.

IV. EVALUATION DESIGN

A. Initial Site Visit (August 13 to 14, 1986)

During the initial site visit colorimetric detector tubes were used to measure CO_2 and CO concentrations at various locations within and outside the building. Temperature, and relative humidity (RH) levels were also monitored.

Eleven current employees, jointly selected by management and the union, were informally interviewed. Information was obtained on objectionable odors, ventilation problems, temperature fluctuations, and cigarette smoke. The majority of employees interviewed had noticed gasoline and kerosene odors, but only intermittently (once every one to two months). Among the employees interviewed these odors were not a major concern. As previously mentioned, these odors were suspected to originate from the periodic filling of underground storage tanks at a gasoline station adjacent to the office building. No gasoline or kerosene odors were detected in the office building during the initial or follow-up surveys. For this reason no air samples were collected for gasoline or other organic hydrocarbons during this evaluation.

A majority of interviewed workers expressed some dissatisfaction with the ventilation systems in the building The complaints included drafts (both hot and cold), temperature changes, dust on diffusers, poor restroom ventilation, and a perceived lack of fresh air (described by employees as "heavy" or "stale" air). B. Follow-up Visit (September 14 to 16, 1987)

In the follow-up evaluation CO_2, CO, temperature and relative humidity measurements, both within and outside the office building, were again collected. In addition to colorimetric detector tubes, a portable infrared spectrophotometer was used to measure CO_2 both within and outside the office.

The three HVAC units were more closely examined and quantitative air flow measurements were made at all accessible air supplies and returns using an Alnor* Balometer*. The first objective of the ventilation survey was to measure the air flows entering the building to compare them to design conditions. A second objective was to inspect the HVAC units for possible sources of contaminants as well as overall operating condition. A third objective was to examine the units to see if they allowed outside air into the building when the outside air dampers were in their minimum (closed) position. The final objective was to compare the ventilation results with the CO_2 and psychrometer measurements.

The following methods were used to evaluate the air handling units.

1. Total air flows out of the supply air diffusers and into the return air grilles were measured using an Alnor Balometer (Model 6465).

2. Total air flows into the exhaust registers in the restrooms were also made using the Balometer.

3. The side panels for all of the air handling units were removed and the units inspected. The inspection included the condition of the filters, the minimum position of the outside air dampers, and the condition of the evaporator condensate pan (ie. whether it contained any foreign material such as mold, etc.). Other unusual findings from the units were also noted.

V. EVALUATION CRITERIA

A. Air Contamination Evaluation Criteria

The primary sources of air contamination criteria generally consulted include: (l) NIOSH Criteria Documents and Recommended Exposure Limits (RELs), (2) the American Conference of Governmental Industrial Hygienist's (ACGIH) Threshold Limit Values (TLVs*), (3) the U.S. Department of Labor (OSHA) federal occupational health standards, and (4) the indoor air quality standards developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). 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 per day, 40 hours per week for a working lifetime without adverse health effects. The ASHRAE guidelines specify outside air quantities to maintain acceptable indoor air quality and minimum ventilation rates which should be acceptable to the majority of human occupants and not impair health.

Indoor air should not contain concentrations of contaminants known to impair health, or to cause discomfort to a majority of the occupants. For application to the general population, ASHRAE recommends the concentrations of these contaminants not exceed one-tenth of the limits which are used in industry. The rationale for this approach is that the general population is more varied than the industrial population in susceptibility to injury due to greater variation in age and health status. In addition, the industrial population is often under greater health supervision than the general population. In some circumstances using one-tenth of the industrial standards may not be adequate because of odor or irritation problems. Table 1 presents some common indoor air contaminants and their sources.

B. Ventilation Evaluation Criteria

Neither NIOSH nor OSHA have developed ventilation criteria for general offices. Criteria often used by design engineers are the guidelines published by ASHRAE. Until recently, the ASHRAE Ventilation Standard 62-73 (1973) was utilized, but recommendations were based on studies performed before the more modern, air-tight office buildings became common. These older buildings permitted more air infiltration through leaks in cracks and interstices, around windows and doors, and through floors and walls. Modern office buildings are usually much more airtight and permit less air infiltration. Due to the reduced infiltration, ASHRAE questioned whether the 1973 minimum ventilation values assured adequate outdoor air supply in modern, air-tight buildings.

Subsequently, ASHRAE revised its standard and published ASHRAE 62-1981, "Ventilation for Acceptable Indoor Air Quality."[1] This standard is based on an occupant density of 7 persons per 1000 square feet (ft^2) of floor area, and recommends higher ventilation rates for areas where smoking is permitted. ASHRAE also recommends that contaminants, such as various gases, vapors, microorganisms, smoke, and other particulate matter, be controlled so that concentrations known to impair health or cause discomfort to occupants are not exceeded. However, the threshold levels for health effects from these exposures are poorly documented. For "general offices" where smoking is not permitted, the rate recommended by 62-1981 is 5 cubic feet per minute (cfm) of outdoor air per person. Higher ventilation rates (20 cfm per person) are recommended for spaces where smoking is permitted because tobacco smoke is one of the most difficult contaminants to control at the source. Areas that are nonsmoking may be supplied at the lower rate (5 cfm/person), provided that the air is not recirculated from, or otherwise enters from, the smoking areas.[1]

ASHRAE Standard 62-1981 also provides ventilation requirement guidelines for a wide variety of commercial, institutional, residential, and industrial facilities and should be consulted for application to the specific situation under evaluation. It should, however, be noted that in 1988 this standard is expected to be replaced with ASHRAE Standard 62-1981R.[2] The revised standard increases the outside air requirements needed over its predecessor. Therefore, 62-1981R was used to specify the outside air needed for the Social Security Building.

C. Building-Related Illness Episodes

Building-related illness episodes have been reported more frequently in recent years as buildings have been made more air-tight to conserve energy and to reduce air conditioning expenses. Modern high-rise office buildings are constructed primarily of steel, glass, and concrete, with large windows that cannot be opened, thus making the building totally dependent on mechanical systems for air conditioning. Contaminants may be present in make-up air or may be introduced from indoor activities, furnishings, building materials, surface coatings, air handling systems, and the building occupants. 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 ascribed to an airborne contaminant, such as formaldehyde, tobacco smoke, or insulation particles, but most commonly a single cause cannot be pinpointed.

Imbalance or malfunction of the air conditioning system is commonly identified, and in the absence of other theories of causation, illnesses are usually attributed to inadequate ventilation, heating/cooling, or humidification.

D. Carbon Dioxide

Carbon dioxide is a normal constituent of exhaled breath, and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of fresh outdoor air are being introduced into a building or work area. The outdoor, ambient concentration of CO_2 is usually 250 to 350 ppm. Typically the CO_2 level is higher inside than outside (even in buildings with few complaints about indoor air quality). However, if indoor CO_2 concentrations are more that 1000 ppm (3 to 4 times the outside level), there is probably a problem of inadequate outside air and complaints such as headache, fatique and eye and throat irritation are frequently found to be prevalent. Although the CO_2 is not responsible for these complaints, a high level of CO_2 does indicate that other contaminants in the building may also be increased and could be responsible for employee health problems.

The OSHA Permissible Exposure Limit (PEL) and the ACGIH TLV* for CO_2 is 9,000 ppm for an 8-hour TWA.[3,4] The NIOSH Recommended Exposure Level (REL) is 10,000 ppm for a 10-hour TWA.[5] These industrial limits, however, are not applicable to the much lower exposures commonly encountered in office buildings.

E. Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials. Major sources of human exposure to CO are engine exhaust, tobacco smoking, and combustion products from inadequately ventilated appliances and heaters that use natural gas, propane, kerosene, or similar fuels. On inhalation, CO acts as a metabolic asphyxiant, causing a decrease in the amount of oxygen delivered to the body tissues.[6] Carbon monoxide combines with hemoglobin (the oxygen carrier in the blood) to form carboxyhemoglobin, which reduces the oxygen-carrying capacity of the blood. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea.[6] These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma and death may follow if high exposures continue without intervention. Long-term, low-level exposure to CO can increase the risk of heart attack for some people.[6]

The OSHA PEL and ACGIH TLV for CO is 50 ppm, 8-hour TWA.[3] The NIOSH REL for CO is 35 ppm for an 8-hour TWA; 200 ppm for a 15-minute ceiling exposure.[6]

E. Temperature and Relative Humidity

The majority of references addressing temperature and humidity levels as they pertain to human health frequently appear in the context of assessing conditions in hot environments. Development of a "comfort" chart by ASHRAE presents a comfort zone considered to be both comfortable and healthful. This zone lies between 73°and 77°F (23° and 25°C) and 20 to 60 percent relative humidity.[7] Recommended design conditions are an effective temperature and dry bulb temperature of 76°F (24.5°C), a relative humidity of 40 percent, and an air circulation rate of less than 45 feet per minute. Effective Temperature is an index of relative comfort determined by successive comparisons of individuals to different combinations of temerature, humidity, and air movement. Relative humidity levels below 30 percent are associated with increased discomfort and drying of the mucous membranes.[8]

F. Tobacco Smoke

Tobacco smoke contains several hundred toxic substances, the more important of which are: carbon monoxide, nitrogen dioxide, hydrogen cyanide, formaldehyde, hydrocarbons, ammonia, benzene, hydrogen sulfide, benzo(a)pyrene, tars, and nicotine. Tobacco smoke can irritate the respiratory system and, in allergic or asthmatic persons, often results in eye and nasal irritation, coughing, wheezing, sneezing, headache, and other related sinus problems. People who wear contact lenses often complain of burning, itching, and tearing eyes when exposed to cigarette smoke. Of the 15 studies published to date which have examined the link between passive smoking and cancer, only three have not shown a statistically significant positive correlation between the two.[9] Active cigarette smoking remains the leading cause of lung cancer in the United States.

VI. RESULTS

The interior CO_2 levels ranged from 800 to 1000 ppm (400 ppm outside) in the office areas checked on August 13-14, 1986. During the follow-up evaluation on September 14-16, 1987 the CO_2 concentrations ranged from 550 to 1200 ppm (outside levels ranged from 350 to 450 ppm). The highest levels were measured in the open office area, an expected finding considering the higher population density. Carbon monoxide concentrations during both the initial and follow-up visits were negligible (less than 5 ppm). Table 2 presents the CO_2, temperature, and RH levels measured during the follow-up evaluation.

The dry-bulb temperatures measured during the follow-up visit ranged from 72 to 77°F over the day (average of 74°F). For the rooms on the ACME air handling unit, the dry-bulb temperatures ranged from 68 to 78°F on the day of the survey and averaged 73°F overall. Dry-bulb temperatures outside the building ranged from 67 to 78°F (average of 74°F).

Relative humidity in the general office area during the second follow-up evaluation ranged from 39 to 50%, averaging 41% overall. For the rooms serviced by the ACME air handler, the R.H. rangedfrom 38 to 48% (averaging 43%). Outside relative humidity ranged from 44 to 62% over the day, averaging 53%.

Comparison of the average temperature and relative humidity with ASHRAE Standard 55-1981 shows that the Trane and York units were maintaining acceptable conditions. The ACME unit, however, was marginally effective. The ASHRAE recommended temperature and relative humidity conditions are summarized in Figure 3.

All of the air flow measurements for the building are shown in Figure 2 except the measurements for the restroom exhaust. The air distribution for these bathroom registers was not considered as significant as the distribution from the supply diffusers in the office areas.

VII. DISCUSSION

The following results show that all HVAC units are supplying air at a rate far below design. Unfortunately, no previous test and balance results were available to show whether the units ever met design criteria.

Air Handling Unit	Design	Actual	% of Design
Acme unit:			
Branch A	1700	1080	63.5
Branch B	2400	1480	61.7
Branch C	1500	1260	84.0
Branch D	1380	1110	80.4
Acme unit, total	6980	4930	70.6
York unit, total	7980	4530	56.8
Trane Total	7980	4250	53.3
Restroom exhaust, total	2250	940	41.8

Using a projection of 65 total employees (four employees in the perimeter offices and 61 in the general office area) and an average of 30 vistors, the Trane and York HVAC units would need to supply outside air for 91 people (61 office, 30 public). According to 62-1981R, the minimum outside air needed for office spaces is 20 cubic feet per minute (cfm)/person. Therefore, 1820 cfm (20 cfm/person x 91 people) minimum of outside air should be supplied by the York and Trane air handling units. Assuming that the air in the open area of the building distributes contaminants evenly, the outside air requirements should be evenly divided between the York and Trane air handling units. Thus, the percentage of outside air for these units, using their design air flows, should be at least 11% (1820/(7980 x 2)) of the total air supplied by the units at all times. Since the total actual air flows from these units are less than design, the percentage of needed outside air is actually 21% (1820/4530 + 4250). Because air in the public waiting area could be more stagnant than in the general office due to differences in the population density of the two areas, a greater portion of the outside air could be allotted to the Trane air handling unit which services the public waiting area.

The outside air requirements for the ACME unit are less clear because of the smoking area located in the lunch room and the intermittent use of some of the perimeter rooms. For example, employees are in the lunch areas for one-half hour or less during the day and the computer room is used intermittently. For these spaces, continuous outside air is not needed. On the other hand, the storage/mail room and the three perimeter offices require constant outside air since they are occupied throughout the work day. Another complication is that some rooms are used intermittently for training, resulting in a varying number of employees in these areas. During training periods involving large groups of workers, the outside air requirements for these rooms would dramatically increase.

To analyze the ACME unit, outside air requirements were specified for the various rooms according to 62-1981R. Ultimately, the area requiring the most outside air was selected as the critical space, and its percent of outside air needs was used as the requirement for the ACME unit. The restrooms, computer room, and lunch rooms are intermittently occupied and outside air to these areas is supplied by the Trane and York units from adjacent spaces (termed transfer air). If these rooms were occupied by employees all the time, as are the offices, outside air would need to be specified for the spaces.

As Table 3 shows, the offices located in rooms 120 and 121 were the critical spaces since they require the highest percentage of outside air (9.5%). Therefore, 663 cfm of the design air flow is required for the ACME unit.

Smoking areas warrant further discussion because of information recently presented at ASHRAE's Indoor Air Quality Conference, April, 1988. Papers presented at this conference showed that particulates from smoking may be filtered out by available HVAC filters, but filters for the gaseous products of smoking are questionable. Since air is normally returned to the air handling unit for recirculation, the gaseous products of smoking in the return air could pass through the filters and be recirculated throughout the building.

Because of filter inefficiencies, the smoking products being diffused throughout a space, and the potential health hazards associated with inhalation of side stream smoke, the policy of a separate, controlled smoking area should be continued with some modifications. Air from the smoking area should be exhausted directly outside and not recirculated.

Furthermore, the amount of exhaust air should be greater than the supply air to prevent contaminated air from escaping from the smoking room. At least 10% more exhaust air than the supply air is required to achieve this condition. Based on the 1200 cfm design flow specified for the smoking room, the exhaust flow should be at least 1320 cfm. To achieve this, an exhaust fan may be installed in the outside wall opposite the doors. In addition, the return air grilles should be closed so the room air cannot return to the air handling unit.

It is important to note that a 1320 cfm flow would create an air velocity through the room's 3' x 7' door of only about 63 feet per minute (fpm). However, since air is supplied to the room by the ACME unit, only 120 cfm of air is actually pulled through the door. This works out to a velocity of only 6 fpm. A velocity of 50 fpm is considered to be ambient air movement. If the other door in the room is opened at the same time, the velocity would be far less. To decrease the chance of contaminated air spilling from the smoking room into the surrounding spaces, the doors should be equipped with closers. This may require that the doors have grilles installed to allow air into the room from the surrounding spaces. The grilles should be sized so that the pressure drop across them does not affect the exhaust fan flow.

Employees had access to all of the thermostats and the main shutoff on the ACME unit. Although they were not permitted to operate the controls on the air handling units, employees were observed adjusting the thermostats. In fact, during the survey, the ACME unit was found shut down after lunch one day, reportedly because one employee found it was too cold in the lunch area.

The zone thermostat for the offices in the northwest corner of the building is located in Room 120. This office has a very low measured air flow (55 cfm). This means that the room with the poorest air exchange was controlling the temperatures in the other offices on that zone. Accordingly, when the temperature changes in other offices, the air handling unit would be slow to react. There is also the possibility that the HVAC unit may overshoot its setpoint, resulting in the other offices being overheated or overcooled.

Gasoline vapors in the building originate from venting of the underground gasoline storage tanks of the service station adjacent to the Social Security building. These vents are approximately at roof level and just south of the building. Under the correct wind conditions (south to southeast), vapors from the vents could be blown toward, and pulled into, the roof top air handling units. As the outside air dampers of the air handling units modulate open, the potential for vapors to enter the units becomes greater. The vapors would be the greatest when the underground tanks are being filled.

Several additional problems were observed with the ventilation systems during this evaluation. First, one of the supply air diffusers on the Trane system was connected to the return air. Therefore, instead of supplying air to the building, the diffuser was pulling air from the building. Second, although an inspection of the ACME unit showed that the filters were relatively clean, debris was found in the standing water of the condensate pan and corrosion was observed on the bottom of the heat exchanger. Debris was also found on the cooling coil. This debris could contain, and be a substrate for, microorganisms which could, in turn, be transported into the building in the air from the air handling unit.

The York unit had clean filters and little water standing in its condensate pan. This unit, however, had a loose fan belt which generated a loud noise noticeable inside the office building. On the Trane unit, natural gas was detected on the valve side of the units heat exchanger. It was not determined if gas was entering the building and the size of the leak was not investigated. This unit also had water standing in the condensate pan and the blower housing. In fact, the water in the condensate pan was deeper on the side of the unit opposite from the pan's drain. The water in the pan and the blower housing contained debris which could contain and serve as a substrate for microorganisms. These microorganisms could be transported into the building in the air from the air handling unit.

The restrooms had a measured total exhaust flow of 890 cfm. This is just 39.6% of design. In addition, because of the low flows, the restrooms would be under slightly positive pressure (an air flow surplus of 30 cfm) meaning that odors generated in the rooms could be pushed into the open area of the building. One reason for the low exhaust flows could have been the observed accumulation of dust-like debris on the registers. This debris reduces the open area of the registers, choking off the air flow. Debris accumulations were also found on other return air grilles, for example in the lunch rooms.

VIII. CONCLUSIONS

One reason for the increase in the CO_2 levels in the building during the day appears to be that the York and Trane HVAC units are cycled on and off instead of running continuously. This means that fresh air is not being brought into the building on a constant basis. In contrast, ASHRAE, in establishing their standards, recommend continuous outside air to be introduced into a building. Another reason for the gradual CO_2 increase may be that the air handling units are not bringing in enough outside air to dilute contaminants generated in the building. Determination of whether this was the problem could not be made based on inspection of the dampers. A final, less likely reason could be short-circuiting between the supply and return grilles. The reason this seems unlikely is that many supply diffusers were located far from the returns, suggesting that short-circuiting would not be a problem. The CO_2 data also showed uniformity throughout the spaces.

IX. RECOMMENDATIONS

1. The output flow rate of all of the air handling units should be checked and then readjusted to as near design as possible. Total flow coming from the diffusers was less than what could be attributed to measurement error. This indicates that the flows of the air handling units has depreciated from original design, assuming that the air flows were ever at design. Maintenance of the belts and cleaning of the heat exchangers and coils may get the units back to design. If not, the blower speed may need to be increased.

2. Once the air flows from the air handling units are brought up to design, the air flows from the diffusers should be rebalanced to design. Air flow measurements at the diffusers, despite depreciated air flows from the air handling units, was not proportional to design values. Increasing the air flows may make the air distribution from the diffusers near to design. However, this must be checked, and adjustments made to the diffusers, if actual flow remains significantly different from design.

3. The outside air dampers of the Trane and York units should be set to provide a minimum of 910 cfm of outside air (approximately 11% of the design flow). This percentage would increase if the units are operating at less than design. If either unit is operating at less than design flow, the correct percentage of outside air can be found by dividing 910 by the actual air flow for the unit and multiplying by 100. If the air in the east or west portions of the open office area remains "stale", more outside air may be pulled from the unit servicing that area. A test and balance contractor can adjust the minimum damper position using mass balance, or outside, return and mixed air temperatures. Minimum damper position can also be set using measured supply and return air flows. Setting the minimum damper position based only on observation is not recommended.

4. The blowers in both the Trane and York HVAC units should operate continuously. Only the heating or cooling coils on these systems should be cycled by the thermostat. By running continuously, contaminants (odors, irritants, etc.) in the general office area can be diluted by the fresh air brought in by the units. Constant operation of the blowers would also mix the air, creating more uniform temperatures and reducing air stagnation.

5. The outside air dampers for the ACME units should be set to provide a minimum of 20 cfm of outside air for the critical space on the system (either Room 120 or 121). This is about 9% of the design flow. Again, however, this percentage would increase if the unit is operating at less than design flow. If not operating at design, the correct percentage of outside air would be found by dividing 20 by the rebalanced air flow for Room 120 or 121 and multiplying by 100. As before, a test and balance contractor should know how to set the dampers using mass balance, or outside, return and mixed air temperatures. Minimum damper position can also

be set using measured supply and return air flows. Setting the minimum damper position based only on observation is not recommended.

6. Because some rooms supplied by the ACME air handler have intermittent use (i.e. for training), some method of supplying a correct amount of outside air during training periods must be investigated. Three possible options are: (1) designing the system to supply the amount of outside air needed for training sessions at all times; (2) installing a control system on the ACME unit which, when actuated, changes the damper position to allow the correct percentage of outside air (20 cfm/person multiplied by the number of people in the space divided by the space's air flow and multiplied by 100) into the ACME unit; or (3) installing additional air handling unit(s) to supply the needed amount of tempered outside air to the spaces during training periods. The first option, although the easiest to accomplish, could be the most expensive alternative in the long run. The second option may be the least expensive, but the ability of the ACME unit to properly temper the increased amount of outside air during temperature extremes needs to be analyzed. The third option may have the greatest initial cost but may be the least complicating. If either Option 2 or 3 is used, personnel in the building will need to be trained to operate the controls on the ACME or the new units. Regardless, the operation of the controls should be restricted to only trained individuals.

7. The operating temperatures of the ACME unit should be corrected to bring space temperatures to within the zone recommended by ASHRAE (shown on the chart in Figure 3). A program to periodically monitor the temperature and humidity in the building should also be initiated.

8. Because of the inefficiency of current HVAC filter systems for controlling the products of smoking, and the potential for the diffusion of smoking products into the building air, the air from the smoking room should not be returned for recirculation to the building. The designated smoking room should be equipped with an exhaust fan with a capacity of at least 1320 cfm. This fan should be installed on a side of the room opposite the doors, possibly in the wall. Doors to the room should be provided with door closers to keep the doors shut. Furthermore, the need for grilles in the doors to allow air from the surrounding space into the room should be investigated. If used, the grilles should be sized so the pressure drop across them does not decrease the exhaust fan flow.

9. All of the return air grilles, and the registers in the bathrooms, should be thoroughly cleaned. Debris on the grilles and registers can severely reduce the air flow, decreasing system efficiency. These registers and grilles should be cleaned routinely on a schedule determined by local conditions.

10. Access to the thermostats and HVAC controls, located in the general office areas, should be limited to qualified personnel. Employees should be locked out of all of the HVAC controls and only trained individuals should be responsible for operating the systems.

11. The supply diffuser which is connected incorrectly to the return system of the Trane unit should be connected to the supply side of the unit. The hole left in the return system should then be sealed.

12. To prevent uptake of gasoline vapors into the building during filling of the underground tanks at the adjacent service station, the station should be requested to have their tanks filled during non-working hours. If the station is unwilling

or unable to do this, then a by-pass control system on the outside air dampers of the air handling units may need to be installed to close the dampers. A device should be also be installed to automatically reopen the dampers to minimum position after a set time or to warn that the dampers are closed.

13. The condensate pans on the ACME and Trane HVAC units should be adjusted so that water drains properly. The inside of the units should be thoroughly cleaned.

14. The natural gas leak in the Trane unit should be found and corrected.

15. The loose belt on the York unit should be tightened.

16. The heat exchanger on the ACME unit should be tested to assure that it does not leak and any visible corrosion on the exchanger removed.

17. The filter on the air conditioning unit located in the computer room should be changed.

18. A formal, written complaint system should be set up for the employees to report problems with the environmental conditions of the building. A formal written complaint system increases communications and reduces spurious complaints. As a minimum, the date, time, the complainant's name, location of the problem, nature of the complaint, and other information the complainant feels is relevant should be recorded. The responsible party acting on the complaint should record the time and date that the problem was acted on, and what was done to resolve the problem. The complaint and complaint action should be recorded on a designated form and a file for each of the air handling units should be set up which would contain this information.

19. A manual should be developed for each of the air handling units and copies kept in each unit's respective file along with any changes made to the units. The manual should include instructions for operating the unit, control schematics, manufacturer's literature on the control components, applicable drawings, a parts list, and other information deemed important to make the unit operate per design. As mechanical contractors change, these manuals will assist the new contractor(s) with learning the systems. The manuals should be be kept up-to-date by recording changes to the HVAC units.

20. A maintenance schedule should be developed for the ventilation systems. The time and date of the maintenance, and the work performed, should be recorded in the file of the appropriate unit.

X. REFERENCES

1. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. ASHRAE standard 62-1981, ventilation for acceptable indoor air quality. Atlanta, Georgia: ASHRAE, 1981.

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XII. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Social Security District Office, Philadelphia, Pennsylvania.
2. American Federation of Government Workers, Local 3231.
3. The National Institute for Occupational Safety and Health (NIOSH) Cincinnati Region
4. The Occupational Safety and Health Administration (OSHA) Region III.

For the purpose of informing 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.

Table 1

Examples of Organic Compound Types and
Potential Indoor Sources

Social Security District Office
Philadelphia, Pennsylvania
HETA 86-356

Pollutant Type	Example	Indoor Sources
Aliphatic hydrocarbons	Propane, butane hexane, limonene	Cooking and heating fuels, aerosol propellants, cleaning compounds, refrigerants, lubricants. flavoring agents, perfume base
Halogenated hydrocarbons	Methyl chloroform, methylene chloride, PCBs	Aerosol propellants, fumigants pesticides, refrigerants, and degreasing, dewaxing, and dry cleaning solvents
Aromatic hydrocarbons	Benzene, toluene, xylenes	Paints, varnishes, glues, enamels, lacquers, cleaners
Alcohols	Ethanol, methanol	Window cleaners, paints, thinners, cosmetics, adhesives, human breath
Ketones	Acetone	Lacquers, varnishes, polish removers, adhesives
Aldehydes	Formaldehyde, nonanal	Fungicides, germicides, disinfectants, artificial and permanent-press textiles, paper, particle boards, cosmetics, flavoring agents, etc.

Table courtesy of: Indoor Air and Human Health, 1985, page 391.

Table 2

Results of Carbon Dioxide, Temperature, and
Relative Humidity Measurements

Social Security District Office
Philadelphia, Pennsylvania
September 15, 1987
HETA 86-356

Time	Location [a]	CO_2 [b] °F	Temperature Humidity, %	Relative
0845 to 0925	A	600	74	50
	B	650	75	48
	C	650	75	44
	D	650	75	44
	E	650	75	48
	F	600	74	46
	G	600	77	45
	H	550	74	46
	I	550 (600)[c]	74	46
	J	550	75	48
	K	550	75	44
	L	400 (400)	67	62
	M	650	-	-
1030 to 1105	A	600	73	39
	B	700	74	40
	C	750	75	40
	D	850	75	40
	E	750	75	40
	F	700	74	40
	G	800	78	39
	H	650	74	43
	I	650	68	46
	J	650	72	42
	K	600	70	40
	L	-	-	-
	M	700	76	38
	N	350 (450)	73	53

(Table continued)

[a] Locations identified in building diagram, Figure 1.
[b] Carbon dioxide, expressed in parts per million
[c] Carbon dioxide concentration, in brackets, measured with colorimetric detector tubes.

Table 2, Continued

Results of Carbon Dioxide, Temperature, and
Relative Humidity Measurements

Social Security District Office
Philadelphia, Pennsylvania
September 15, 1987
HETA 86-356

Time	Location [a]	CO_2 [b]	Temperature °F	Relative Humidity, %
1215 to 1240	A	750 (800)	74	40
	B	800	74	40
	C	800	73	42
	D	850 (1000)	73	42
	E	800	74	40
	F	750	72	41
	G	800	77	39
	H	650	73	42
	I	600	69	47
	J	650	73	39
	K	600	69	43
	L	350	76	44
	M	750	76	38
	N	-	-	-
1420 to 1450	A	800	76	41
	B	850 (1000)	77	42
	C	850	76	41
	D	900 (1250)	75	44
	E	850	75	44
	F	850	73	46
	G	750	78	39
	H	650	75	44
	I	650	69	47
	J	700	74	43
	K	600	71	44
	L	-	-	-
	M	800	76	44
	N	300	78	52

[a] Sampling locations identified in building diagram, Figure 1.
[b] Carbon dioxide, expressed in parts per million
[c] Carbon dioxide concentration, in brackets, measured with colorimetric detector tubes.

Table 3
Outside Air Needed for ACME Air Handling Unit
at
Social Security Administration Building, Phildelphia, PA
HETA 86-356

Location	Room Number	Outside Air According to 62-1981R	Total Outside Air Needed	% Outside Air to Design Air
Office	104	20 cfm/person	20	6.7
Women's Public Restroom	106	Transfer Air	0	0.0
Men's Public Restroom	107	Transfer Air	0	0.0
Men's Employee Restroom	108	Transfer Air	0	0.0
Women's Employee Restroom	109	Transfer Air	0	0.0
Women's Lounge	110	Transfer Air	0	0.0
Lunch Room	112	Transfer Air	0	0.0
Smoking/Lunch Room	113	Transfer Air	0	0.0
Storage/Mail Room	114	20 cfm/person	20	1.8
Training Room	115	Transfer Air	0	0.0
Computer Room	117	Transfer Air	0	0.0
Office	120	20 cfm/person	20	9.5
Office	121	20 cfm/person	20	9.5
Office	124	20 cfm/person	20	5.0
Other Spaces on ACME Unit	---	Transfer Air	0	0.0

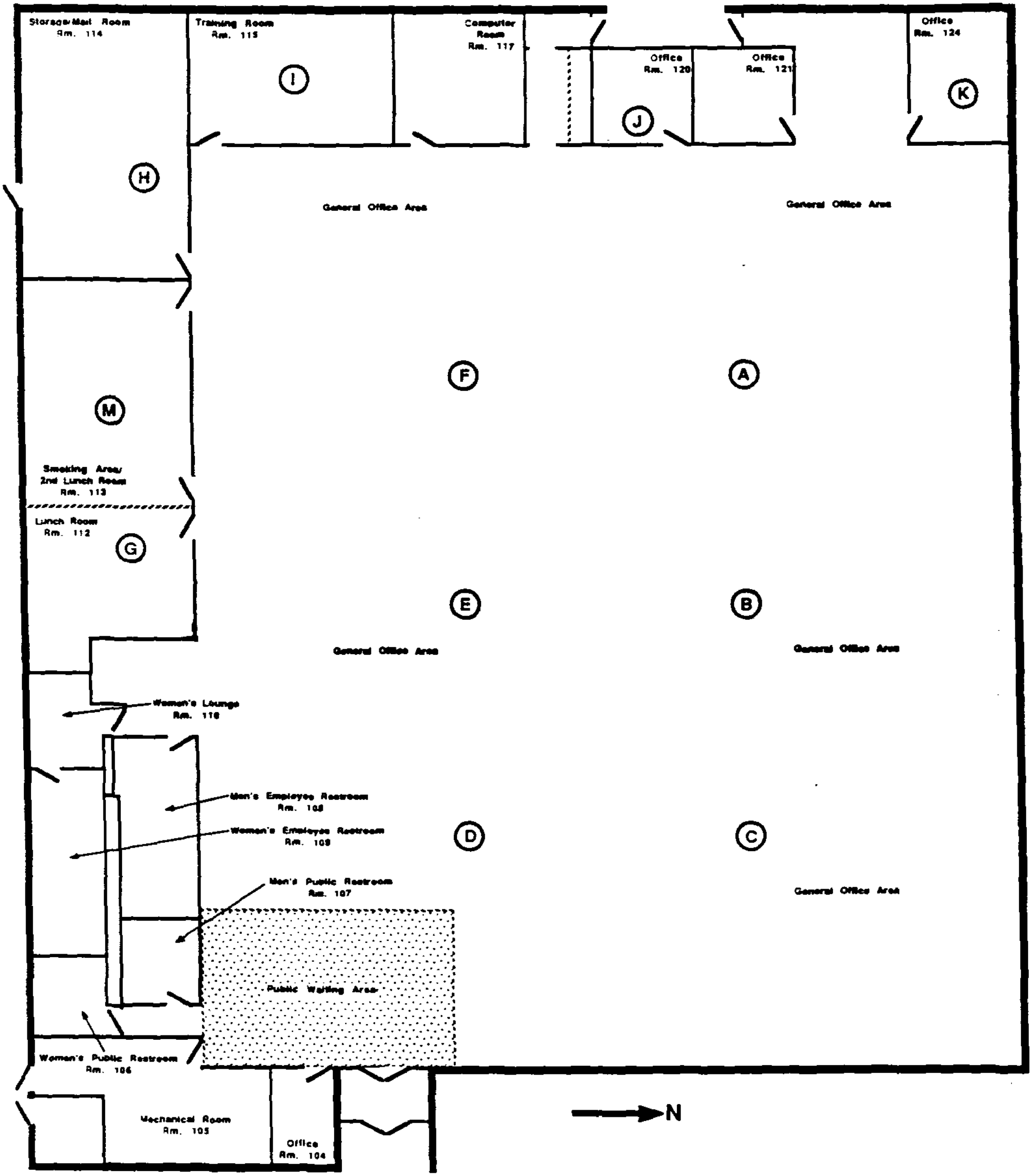
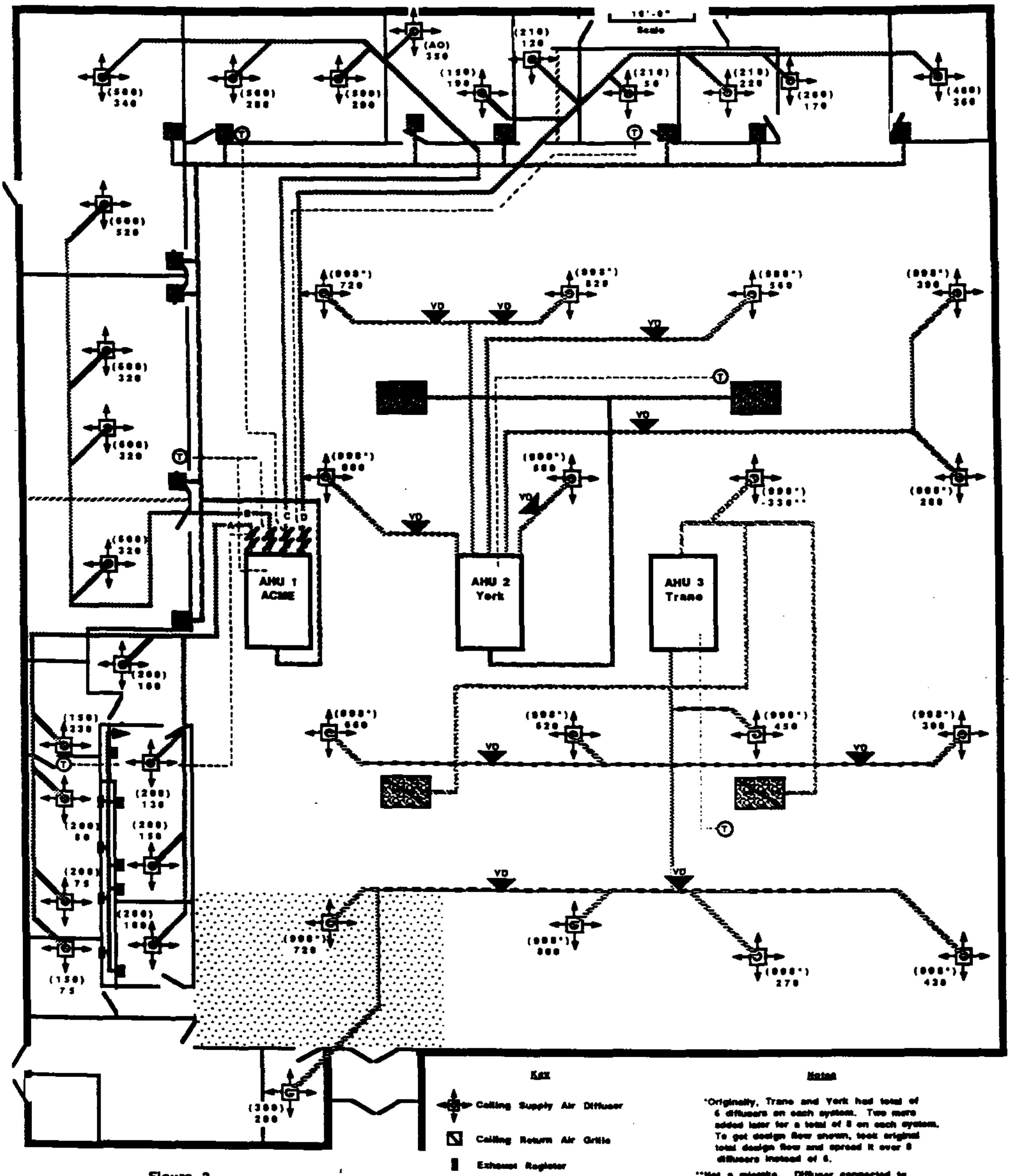


Figure 1
Sample Locations
Social Security Administration Building
Philadelphia, PA
HETA 86-356



Key

Ceiling Supply Air Diffuser

Ceiling Return Air Grille

Exhaust Register

Thermostat

VD Volume Damper

Hot & Cold Deck Damper System

Notes

*Originally, Trane and York had total of 6 diffusers on each system. Two more added later for a total of 8 on each system. To get design flow shown, took original total design flow and spread it over 8 diffusers instead of 6.

**Not a mistake. Diffuser connected to return system of unit.

Figure 2
Ventilation Schematic and Measurements
Social Security Administration Building
Philadelphia, PA
HETA 86-356

Figure 3
Acceptable Ranges of Temperature and Relative Humidity

Social Security Administration Building
Philadelphia, PA
HETA 86-356

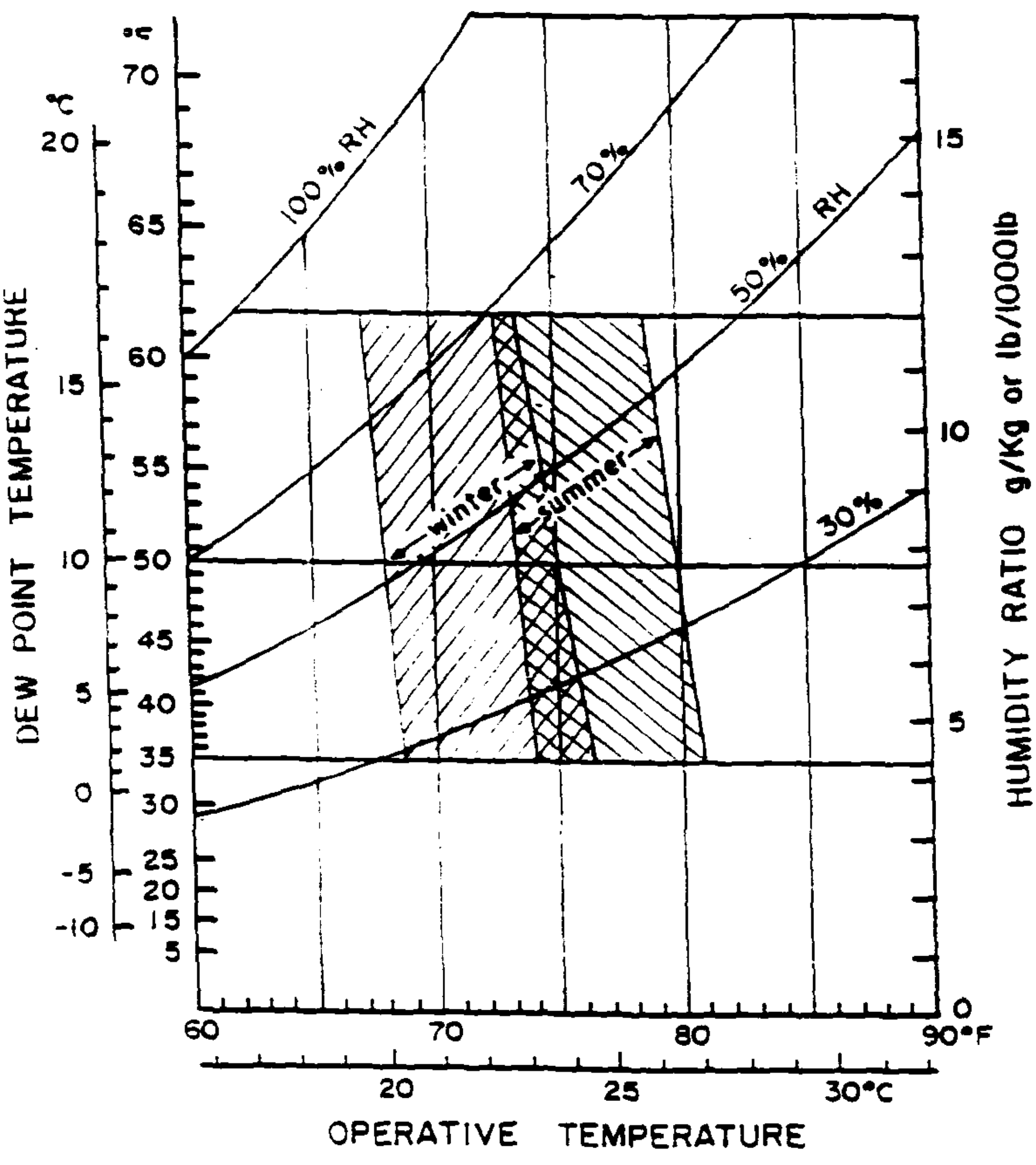


Table courtesy of: The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.
Standard 55-1981, "Thermal Environmental Conditions for Human Occupancy"