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I. SUMMARY

On September 6, 1988, the National Institute for Occupational Safety and Health (NIOSH) received a Health Hazard Request from the Raymond W. Bliss Army Community Hospital in Fort Huachuca, Arizona. The request was to investigate the cause of Indoor Air Quality (IAQ) type symptoms at Greely Hall located on the Fort Huachuca Army Base.

On January 24-27, 1989, representatives from NIOSH conducted an environmental and ventilation survey at Greely Hall. During the survey, carbon dioxide (CO_2) concentrations, and dry and wet bulb temperatures were measured. In addition, inspections were made of the air handling units in the building.

Carbon dioxide measurements were taken three times during the day of the survey. The average CO_2 levels were 584 parts per million (ppm) in the morning increasing to 1040 ppm for the last measurements made that day. However, the levels ranged from 350 to 1000 ppm in the morning to 800 to 1800 ppm in the afternoon. Outdoor levels ranged from 350 to 400 ppm.

Wet and dry bulb temperature measurement were made twice on the day of the survey. The average temperature and relative humidity measured were 74°F and 33% in the morning and 76°F and 29% in the afternoon, respectively. Ranges for the temperature were 70 to 77°F in the morning and 73 to 78°F in the afternoon. Ranges for the relative humidity were 28 to 41% in the morning and 24 to 43% in the afternoon. Outdoor temperatures and relative humidities were 53°F and 70% in the morning and 64°F and 57% in the afternoon, respectively.

Inspection of the air handling units showed that many of the units had inoperable or closed main outside air dampers. Maintenance on the units was also assessed to be poor. Some other factors which were identified as potentially causing problems were improperly maintained or poorly draining condensate pans, renovation of the building without upgrading the ventilation systems, and insufficient maintenance personnel.Based on these results, that the potential for thermal comfort problems and microbial contamination exist at Greely Hall. Recommendations to solve the problems are included in Section VII of this report.

Key Words: SIC 9711 (National Security), ventilation, indoor air quality, carbon dioxide, temperature, relative humidity, maintenance practices.

II. INTRODUCTION

On September 6, 1988, the National Institute for Occupational Safety and Health (NIOSH) received a Health Hazard Request from a representative of the U.S. Army at Raymond W. Bliss Army Community Hospital in Fort Huachuca, Arizona. The request was to investigate the cause of Indoor Air Quality (IAQ) type symptoms at Greely Hall located on the Fort Huachuca Army Base.

On January 24-27, 1989, representatives from NIOSH conducted an environmental and ventilation survey at Greely Hall. Recommendations were made during a close-out meeting on the last day of the survey and sent by mail.

III. BACKGROUND

A. Building Description

Greely Hall is a three-story, multi-purpose building with approximately 120,000 feet per floor. At the time of the survey, the building housed mainly offices, but the building also had a cafeteria, auditorium, computer rooms, conference rooms, and an electronics maintenance area. Over 2,100 people work in the building, mainly on one shift.

Greely Hall was apparently built in two parts as shown by Figure 1. The original building, composed of the North, South, and East Wings, was constructed in the late 1950s. The Northeast and Southeast Wings were added sometime in the early 1960s. Originally, the building was used as an electronics development laboratory and had many open areas. However, the building was changed to primarily offices by adding walls in the open areas to create more offices. Currently, the building is a mix of small, enclosed office areas and large open areas. The construction of the area is usually dictated by the group which is occupying that part of the building. Future plans are to convert the building to a classroom facility.

Several different groups occupied the building. Reportedly, a group rented space in the building from Fort Huachuca Army Base, and that area of the building would be renovated according to the needs of that group.

B. Description of the Ventilation Systems

Eighteen air handling units were found to supply air to the building. All of the units appeared to be original. However, the duct runs have been changed over the years due to renovations. Mechanical rooms are situated on each floor along outside walls of the building. In general, the outside air intakes are in the side walls of the building next to the mechanical rooms. Discharges for the exhausted portion of the return air were usually located adjacent to the outside air entrances.

Nearly all of the air handling units in the building were dual duct systems with temperature regulating dampers in the branch line ducts. These dampers were controlled by thermostats located in the spaces. Static pressure regulating dampers were located at the air handling units to regulate the air flow in the main ducts, depending on the demand on the system. Most of the air handlers supplied a constant volume of air, but one unit was being converted to a variable air volume system at the time of the survey.

Distribution of the air was originally through circular louvered diffusers. These diffusers supplied air through louvers around the circumference of the diffuser and returned air through the central part of the diffuser. However, in parts of the building, these diffusers had been replaced with square, multidirectional louvered diffusers. Reportedly, in all cases, air was returned through grates in the ceiling instead of through the supply air diffusers.

Air was returned to the air handling units (AHU) via the ceiling space, stub ducts, and a fan-powered return system. All of the bathrooms were connected to exhaust systems which exhausted air from the building through the roof.

C. Smoking Policy

At the time of the survey smoking was allowed in some office areas of the building. The office areas designated to be smoking areas depended on the senior supervisor for the group occupying the area. In one case where smoking was allowed in an open office area, work stations with small ventilation systems (called "pods" by base personnel) were installed. These are described in more detail later in the report.

IV. EVALUATION DESIGN

A. Environmental Evaluation

Carbon Dioxide (CO_2), levels were measured in selected areas of the building during three different time periods on January 25, 1989. The time periods roughly corresponded to early morning as most employees were just arriving, about midway through the work day, and in the afternoon. Temperatures and relative humidity were measured twice during the day (early morning and afternoon). Attempts were made to make measurements in all of the selected areas more than once during the day.

1. Temperature and Relative Humidity Measurements.

Real time temperature and relative humidity measurements were conducted using a Vista Scientific, Model 784, battery-operated psychrometer. Dry and wet bulb temperature readings were monitored and the corresponding relative humidity determined using psychrometric chart.

2. *Carbon Dioxide Measurements.*

Real-time CO_2 levels were determined using a Gastech, Model RI-411A, CO_2 meter. This portable, battery-operated instrument monitors CO_2 (range 0-4975 parts per million (ppm)) via non-dispersive infrared absorption with a sensitivity of 25 ppm. Instrument zeroing and calibration were performed prior to use with zero CO_2 concentration air and a known CO_2 concentration span gas (800 ppm).

B. <u>Ventilation Assessment</u>

The following items were inspected for 15 of the 18 air handlers in the building which served occupied spaces:

1. The minimum and main outside air dampers for position and operating ability.

2. The screen between the outside air dampers and outside the building for debris loading, obstruction, and overall condition.

3. The mixed air plenum for debris.

4. The filters for degree of loading and overall condition.

5. The fan plenum for debris and signs of standing water.

6. The cooling coils and coil drain pans for standing water or signs of standing water, and debris on the coils or in the pans.

7. The duct at the outlet of the heating coil for debris.

In addition to an inspection of the units, readings from the various gages on each unit's control panel were recorded as were the settings and numbers showing on the gages on the pneumatic controllers for the cooling and heating coils (when possible). This information showed how well the control systems on the units were being maintained. Lack of maintenance on the controls can lead to malfunction and cause the units to not supply air at the right temperature to the building. If the units cannot supply adequately tempered air, the occupants will feel uncomfortable which can lead to complaints.

In several rooms, smoke tubes were used to visualize local air flows. The smoke was blown into the room air at about head level and observed. Slow movement or stagnation of the smoke indicates that the air is not moving or mixing well. This can lead occupants to complain about odors or stuffiness.

V. EVALUATION CRITERIA

Specific standards for contaminant levels in office buildings do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards and recommended limits for occupational exposures.[1-3] With few exceptions, pollutant concentrations observed in office work environments fall well below these published standards or recommended exposure limits. The American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) has published recommended building ventilation system design and thermal comfort criteria.[4,5] The bases for monitoring individual environmental parameters are presented below.

A. Temperature and Relative Humidity

The perception of comfort is related to one's metabolic heat production, the transfer of heat energy to or from the environment, physiological adaptation, and body temperature. Heat transfer between the body and the environment is influenced by such factors as air temperature, humidity and movement, the temperature and heat radiating properties of the body and surrounding surfaces, and the insulative properties of clothing. The American National Standards Institute (ANSI)/ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy, specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable[4].

B. Carbon Dioxide Concentrations

Carbon dioxide is a normal constituent of exhaled breath and monitoring the CO_2 levels can be a useful tool to judge whether adequate outside air is being introduced into an occupied space. Indoor CO_2 concentrations (or levels) are normally higher than outdoor CO_2 concentrations which normally range between 200 and 400 ppm. When indoor CO_2 levels are elevated in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 levels can mean that other indoor contaminant concentrations are elevated.

ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, specifies that indoor CO_2 levels be less than 1000 ppm.[5] This level is based mainly on odor perception and comfort, and is far below the level at which adverse health effects from CO_2 would be expected. ASHRAE Standard 62-1989 also recommends ventilation rates of 20 cubic feet per minute (cfm) per person for offices based on a specified number of occupants per 1000 ft^2 of occupied area.[5] By ventilating the building with the proper amount of outside air, ASHRAE believes that CO_2 levels can be kept to less than 1000 ppm and that other contaminants, except unusual sources, will be kept at acceptable levels. This standard further specifies that the outdoor air meet applicable Environmental Protection Agency (EPA) standards for outdoor air. Applicable EPA standards for some contaminants in the outdoor air are listed in the document. The document also requires that contaminant levels in the indoor air meet ambient air standards by EPA and others.

C. Environmental Tobacco Smoke

Environmental tobacco smoke (ETS) contains several hundred identified toxic substances. The following are the more important of these: carbon monoxide, nitrogen dioxide, hydrogen cyanide, formaldehyde, hydrocarbons, ammonia, benzene, hydrogen sulfide, benzo(a)pyrene, tars and nicotine. ETS 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 ETS. Of the 15 studies published to date which have examined the link between passive smoking and cancer, all but three have shown a statistically significant positive correlation between the two.[6] Active cigarette smoking remains the leading cause of lung cancer in the United States.

VI. RESULTS

These observations were made from the inspections of the air handling units:

1. The material for the screens covering the outside air intakes was similar to that used for screen doors. Many of the screens were clogged with debris. In some cases, debris was so heavy that the screen could not be seen through. In one case, the screen had been torn creating the chance for larger debris or birds to enter the filter plenum.

2. On units which had modulating (as opposed to fixed) main outside air dampers (15 of the 18), the dampers on only two of the inspected air handlers were open despite the outside air temperature being in the range where the dampers should have been indexing. The outside air temperature was measured to be 64°F at about the time the units were being inspected. According to the drawings for the system, the damper is supposed to be indexing between 55 and 75°F. The dampers on four of the inspected air handlers were found disabled. Without indexing ability, the amount of outside air entering is limited to that which can be pulled through the minimum outside air damper. The increase in the carbon dioxide readings throughout the day (discussed later in this report) indicates that there is not enough outside air currently entering the building.

3. The minimum outside air dampers for two of the air handling units were found closed. On all other units which had these dampers, the dampers were found open.

4. The doors to the filter plenum on four units were found open. This allowed bypassing of the outside air dampers to an extent. With the door open, air from the mechanical room is pulled into the air handler causing a short-circuit of the outside and return air systems.

5. All of the filters were clean to moderately loaded.

6. The fan plenums on all of the units were relatively free of debris, but the floors of three units had large rust spots, indicating that there had been water standing in them. The source of the water was not obvious.

7. The cooling coil pans for all but one of the air handling units showed signs (heavy rust and debris) of previous standing water. In some cases, debris had formed a barrier around the drain hole in the pan. On several of the pans, the drain was located in the side of the pan and on others the drain was beneath the coil. For the former, water could stand in the pan because the bottom of the drain hole was not even with the bottom of the pan. For the latter, the drain was out of sight and inaccessible for maintenance. Debris and standing water in the coil pans could potentially cause bioaerosols.

8. The one air handling unit which did not have signs of standing water had a new drain pan. Reportedly, the old pan had rusted through. On the new pan, the drain hole could not be found.

9. The outlet ducts for the heating coils on all units were relatively clean. For most of the units, dust accumulations units were no more than what would be expected for their age. In one air handler, however, the dust was heavier than in the others. This one had served a renovation area in the building. Also, the unit serving a part of the building which was undergoing renovation was running at the time of the survey. This is a condition which should be avoided, since dusts generated by renovation can plug filters and coils in air handlers. Furthermore, this dust is a potential nutrient for microbials and an allergen for building occupants.

10. Readings recorded from each unit's control panel showed a wide variation in the temperatures in the hot duct, 75 to 125°F. Normally, such a wide variation would not be expected, particularly when the temperatures outside were in the 50s and 60s. This implied that the resets or the hot deck temperature indicators on these units were malfunctioning.

    The cold deck temperatures shown on the control panel did not vary as widely, but were not uniform. This indicated that some adjustments might have been made in the controllers to compensate for different thermal loads on different units, or that the temperature indicators were malfunctioning.

11. The hot deck controllers showed signs of not being well maintained. The settings on the hot deck controllers were nonuniform and not set according to common recommendations. In addition, the temperatures shown by gages on all of these controllers for hot deck and outside air temperatures did not agree with the readings on the control panels. Temperature readings from the hot deck on some controller gages did not agree with the branch pressure to the hot water valve. On at least five of the units, the hot deck controller was an antiquated electronic controller which had no gages showing temperatures and line pressures.

12. The cold deck controllers were in about the same shape as the hot deck controllers and had similar problems. Most of the valves on the major controllers were fully open according to the pressure indications on the branch line going to the cold water valve. Since the day was mostly cloudy and temperatures were in the 50s and 60s, the coils may have been at maximum cooling capacity. It is likely that the lack of cooling capacity is the reason many of the main outside air dampers have been inactivated because the systems could not handle the cooling load of the outside air and the building.

13. An energy management control system had been added to the units, but was inoperable during the survey. Reportedly, the system had been disconnected because it did not function correctly.

14. Several of the mechanical rooms showed signs of being flooded in the past (residual rust on broad areas of the floor). In addition, many of the drain areas outside of the air handling units showed signs (residual rust marks) of standing water.

The following are other observations made during the survey:

1. Overall, the average temperature in the building increased by two degrees on the day of the survey, as shown in Table 1. Temperatures in some areas had an inordinate increase throughout the day when compared to other areas of the building. In some areas, the temperature increase was as much as 5 °F compared to a 0 to 1 °F increase in others.

   The average relative humidity in the building, shown also in Table 1, decreased slightly over the day (from 33 down to 29%).

2. The average carbon dioxide readings (Table 2) show an increase throughout the day (from 584 to 1040 ppm). In addition, the carbon dioxide readings taken in the morning in some areas were substantially higher than those in the outside air (readings of 800 to 1000 ppm).

3. The building had originally been planned to be a lab, but over the years was converted to offices. In virtually all of the offices, there were computers. Along with the changes in the building were changes in the ventilation system. Reportedly, the ventilation system was not rebalanced after the changes. In some cases, specialty use areas, such as the cafeteria, conference rooms and computer rooms, were added to the same systems serving offices.

4. Smoking policies in the building were left up to the discretion of area supervisors. In some areas, the employees must go outside, to smoke while, in others, the smoker is allowed to smoke in the office area as long as no one complains. Discussions with some of the occupants in offices where the latter policy was in force stated that they did not like the smoke, but were afraid to complain because they did not want to cause trouble.

   In some areas, local smoke collectors or "pods" were installed. The smoker is supposed to blow smoke toward the entrance of the collector. Smoke tubes showed no influence of the collector at the approximate location of the head of a person seated at the pod. All of the smoke blown directly at several collector entrances was not captured. Additional complaints were received about the ineffectiveness of the pods from occupants in the area where they were located. Moreover, routine maintenance schedules for the collectors did not exist.

5. Complaints were received about the poor operation of the exhaust ventilation in at least one lounge. Inspection of one of the men's restrooms revealed that odors were not being properly exhausted.

6. Smoke tube traces in one of the offices which had the original height ceilings and diffusers showed little air movement in the space. Smoke tube traces in another renovated office, which had lower ceilings and new diffusers, showed that the air in the space had more movement but even this movement was very slow.

7. In some areas, the old return system, which pulled air through the center of the diffuser, was capped over with no alternate return system evident. In the rooms which were inspected, return openings into the ceiling plenum were not evident. In one room, a ceiling tile had been removed to allow air to flow into the ceiling space.

8. Attempts were made to get up-to-date drawings for the ventilation system. Up-to-date drawings were never supplied and, reportedly, did not exist. The supplied drawings only showed changes from the original construction. Maintenance personnel only had copies of original drawings. Furthermore, trying to find someone on the base who had a set of the original drawings was difficult because no one knew whom to contact. Drawings were finally supplied a couple of weeks after leaving the base.

9. Only one contractor mechanic was responsible for maintaining all of the air handling units in the building. However, this mechanic was detailed to other buildings when the contractor felt that it was necessary.

10. Reportedly, emissions from a diesel-powered generator located near the cafeteria and Northeast Wing could be smelled in the building.

VII. DISCUSSION AND CONCLUSIONS

The survey at Greely Hall indicated a potential for environmental problems. Findings from the air handling unit inspections, increasing carbon dioxide levels, and increasing temperatures throughout the day in some areas show that comfort and microbiological growth problems could exist in the building.

Several factors appear to contribute to the problems in Greely Hall. The primary factor is poor maintenance on the air handling units and exhaust systems. Poor maintenance was evident by signs of standing water in the cooling coil pans and areas outside of the air handlers, the condition of the parts of the air handler, the condition and lack of calibration of the controllers and control panel instruments, the inoperability of some of the outside air dampers and the bathroom exhaust systems, and the clogged outdoor air screens. Poor maintenance can lead to poor control of the temperatures in the building, inadequate outside air for dilution of contaminants, increased energy costs, and odors migrating between building spaces. Furthermore, poor maintenance on the existing control systems is believed to be partially responsible for the energy saving control systems not working.

Poor maintenance on the air handling units could be related to inadequate manpower, inefficiency of the maintenance staff, and/or a lack of knowledge of system operation. Less than one full man-year is allotted for maintaining all of the air handlers in Greely Hall. Investigation of the air handling units showed that this kind of manpower effort has barely kept the units running. Little time is allowed for properly cleaning the air handling units and related parts, calibrating controls, fixing or replacing defective parts, and effectively diagnosing and solving the building's environmental problems. In addition, inadequate training of maintenance personnel appears to contribute to poor maintenance.

The location of drains on the cooling pans and the debris build-up around the drain holes can lead to standing water in the cooling coil pans. The debris and water serve as a perfect substrate for microbial agents, such as algae, bacteria, and fungi. Byproducts of the microbials could be blown into the work area and cause complaints if the microbials are of the right species and in adequate concentrations to cause problems for susceptible individuals. Bioaerosol problems can also be cyclical. Under normal cooling conditions, the water in the pans may be too cool for effective propagation of most microbials. However, when the interiors of the units heat up, as occurs during night setback or heating conditions, the pan water temperatures could reach the point where rapid microbial growth occurs.

Another main contributor to the problems in Greely Hall is the piecemeal renovation of the building from one use to another without a full evaluation of the effect on the mechanical systems and maintenance. Current use of the building puts a greater cooling demand on the building than originally planned. Current cooling demand on the system appears to equal or exceed the capacity of the current system. Therefore, on days which have a high cooling demand, the temperature in the building can increase, causing discomfort for the occupants.

Further effects on the ventilation system come from the addition of extra ducting and diffusers. Additional ducting can increase the static pressure demands on the system which can further decrease fan output, possibly effect the static pressure controllers in the main ducts of the system, decrease the air flow from existing diffusers, and lower the air flow expected from the new diffusers. A net effect of this situation is changed air flow patterns in the rooms because of decreased air velocity from the diffusers. Lower air velocity at the diffuser leads to decreased mixing in the space, lower velocities in the occupied zone, and the occupants feeling that the air is stagnant.

Constantly adding to existing systems also has an effect on the way the air is distributed to the branch ducts. Additional ducting without rebalancing causes the entire system to be imbalanced so that some occupants get too much air and some occupants do not get enough. Survey results indicate that rebalancing of systems after changes was never done at Greely Hall.

In Greely Hall, ventilation for special-demand areas, such as conference rooms, cafeterias, and computer rooms is provided by the same systems used for offices. These areas requires special control and ventilation. So, by designing or specifying systems expressly for the specialty areas, many problems are prevented. At the time of the survey, several different types of ventilation designs existed, or were being adapted to the building. Each renovation appeared to cause an additional different ventilation design. All of these different systems can become a nightmare to operate, maintain, and keep records on. For example, each system requires different knowledge to operate and maintain, additional parts are required to be kept on hand to maintain the systems, records for the various systems are not uniform, and training time for new people is longer.

Another major factor is the apparent lack of adequate outside air being brought into the building. The low CO_2 levels in most parts of the building in the morning indicate that the building is purged well enough over night. However, inadequate outside air volume is believed to be the reason for the inordinate rise in CO_2 levels in the building throughout the day. During the survey, many of the main outside air dampers had been inactivated probably to compensate for inadequate cooling capacity in the systems. The minimum outside air dampers were originally sized for outside air rates for fewer people. The conditions at the time of the survey did not meet the ASHRAE standards.

The current location of the outside air intakes next to the exhausts can lead to recirculation of exhaust air. This arrangement can be difficult and expensive to correct. If increasing the outside air flow does not decrease CO_2 levels, then either the outside air intakes or exhaust outlets will need to be relocated. In addition, because of the intake locations, any contaminant-generating process near the building, such as test running the generator or truck traffic next to the building, can be a source of contaminants in the building.

Uncontrolled ETS, combined with a lack of outside air, appears to be a major source of complaints in some parts of the building. NIOSH does not recommend smoking in the general work place even if the area is adequately ventilated because of the health effects caused by active and passive smoking.

VIII. RECOMMENDATIONS

Greely Hall's problems appear to require building-wide solutions. The interplay of problems, current condition of the mechanical equipment and piecemeal renovations dictate that short-term solutions are not feasible because solving one problem area could cause new problems or intensify old problems in other areas. For this reason, most of the recommendations offered are long term. The following are general recommendations for the building.

1. Open and honest communication between building occupants, administrators, and other interested parties should be maintained. Open communication and trust are very important while solving an indoor air quality problem. To facilitate communications, a working committee composed of representatives from all of the interested parties should be formed. This committee should be the center of all information exchange so that persons seeking the latest, most accurate information can have a contact point. The exact charter for the committee would be up to the involved parties. However, this committee should not be a place for complaining as explained in the next item.

2. One person should be designated to receive complaints about the building. This person should be a neutral party who does not have reprimand power over the teaching staff. This person should have files set up for the complaints according to air handler or areas subdivided by air handlers. All complaints should be acted upon and, once the problem is resolved, the actions taken should be reported back to the complaint, and filed along with the complaint.

3. A long range plan (5 to 10 years) for the usage of Greely Hall is needed. This plan should designate the general use of the building and then the entire interior design should be specified to reflect the use. In the plan, special use areas, such as computer rooms, conference rooms, and smoking lounges, should be designated and fixed in location. The plan should be flexible enough to adapt for change as reflected in past usage changes in the building.

4. A mechanical design firm should be hired to perform a building-wide energy and mechanical equipment audit to assess whether the current systems have adequate capability and capacity for future use. If the current systems are found to be lacking, the mechanical design firm should then design ventilation systems for the entire building which are uniform and flexible enough to meet current ASHRAE standards and future design changes.

5. A control systems firm should be hired to perform a similar audit on the current and future control systems. They should work with the mechanical firm to develop a control scheme and design schedules.

6. Both the mechanical and controls contractors should provide written theory of design, and operation specifications for their designs. Air flows and other operating parameters (reset schedules, controller settings, design temperatures, etc.) should be listed on the drawings next to the applicable device (diffuser, duct, controller, etc.). Changes to the systems which affect the theory of design should be recorded as an addendum to the original documents.

7. A long-term increase in the number of property trained maintenance personnel is needed so that current and future mechanical and control systems can be properly maintained. An additional short-term increase in the number is needed to get the current systems into proper operating condition and to clean up and organize the mechanical rooms. Maintenance contractor firms should be able to specify how many mechanical staff will be needed and this number should be stipulated in contract bids.

8. Current duct systems which are kept and used in future designs and systems should be tested and balanced upon completion of system installation. Personnel performing the test and balance should be certified by the National Environmental Balancing Bureau or an equivalent certifying organization. Upon completion of the test and balance, the contractor should provide a report which lists as a minimum the instruments and the measurement methods. As part of the instrument information, the instrument settings, for the instrument was used, and special use conditions of the instruments should be listed. Data listed in the report should be the original and final diffuser flow measurements, flow measurements from the main supply ducts, and fan amperage, revolutions per minute, and static pressure.

9. Maintenance schedules should be set up for <u>all parts</u> of the current and future mechanical systems in the building. These schedules should include cleaning of exhaust and return air grates, and checking of exhaust and supply air systems for flow. Schedules should be set up according to manufacturer's and maintenance contractor's recommendations. Maintenance actions and findings should be included in the file for the air handling unit or exhaust system.

10. Files for each of the current and future air handlers and exhaust systems in the building should be established. Each file should contain at least up-to-date mechanical and control system drawings, manufacturer's product literature on each component of the systems, written operation methods for all systems, maintenance schedules and records, and records of changes to the systems. Complaints and their disposition should also be kept in the files of the applicable systems. All drawings, methods, and schedules need to be kept up to date. Files should be kept in the building and in the engineer's office.

11. Drains for the condensate pans in the current air handling units should be corrected so there is no standing water in the pans. In addition, debris should be cleaned out of pans and other parts of the air handling units. All drains should be properly trapped to prevent backflow through the drain. Coil pan drains on future installed air handlers should be checked for drainage to prevent standing water.

12. Filters used in all air handlers should be rated as high in efficiency as possible without substantially affecting the operation of the air handling units. The rated efficiency of the filter should be according to the ASHRAE dust spot test and determined by an independent laboratory. In addition, filters should be changed out according to the manufacturer's rated pressure drop across the filters. Pressure taps may need to be added to the air handlers to facilitate measuring the pressure drop.

13. Operations which generate contaminants that can be pulled into the building's air handling units should be performed outside of routine working hours.

14. Smoking should only be allowed in dedicated enclosed smoking areas or outside the building. Dedicated smoking areas should have local systems which properly exhaust air outside of the building. Replacement air rates of 60 cfm/person should be supplied to the room by the supply air system or infiltration from other areas. Moreover, the smoking room should be kept under negative pressure relative to adjacent areas of the building.

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

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1. Raymond W. Bliss Army Community Hospital
2. HQ USAISC

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Table 1. Temperature and Relative Humidity Summary Data
Ft. Huachuca--Greeley Hall
Ft. Huachuca, AR
HETA 88-369
January, 1989

	Dry Bulb Temperature (°F)			Relative Humidity (%)		
	Mean	S. D.	Range	Mean	S. D.	Range
Morning	74	1.6	70 - 77	33	3.0	28 - 41
Afternoon	76	1.3	73 - 78	29	3.4	24 - 43

Outdoor Dry Bulb Temperatures: Morning-53 °F and Afternoon- 64 °F.
Outdoor Relative Humidity: Morning-70% and Afternoon- 57%.

Notes: The number of data points used to calculate the means, standard deviations (S. D.), and ranges in the tables were Morning-29 and Afternoon-34.

Morning measurements were made between about 6:50 and 7:50 AM and afternoon measurements were made between about 1:05 and 2:50 PM.

Table 2. Carbon Dioxide Summary Data
Ft. Huachuca--Greeley Hall
Ft. Huachuca, AR
HETA 88-369
January, 1989

	Carbon Dioxide (ppm)		
	Mean	S. D.	Range
Early Morning	584	185.1	350 - 1000
Late Morning	830	147.1	500 - 1100
Afternoon	1040	185.4	800 - 1800

Outdoor Carbon Dioxide Levels: Morning-350 ppm and Afternoon-400 ppm.

Notes: The number of data points used to calculate the means, standard deviations (S. D.), and ranges in the tables were Morning-44, Late Morning-40, and Afternoon-53.

Morning measurements were made between about 6:50 and 7:50 AM and afternoon measurements were made between about 1:05 and 2:50 PM. The measurements for Late Morning were taken approximately halfway in-between.

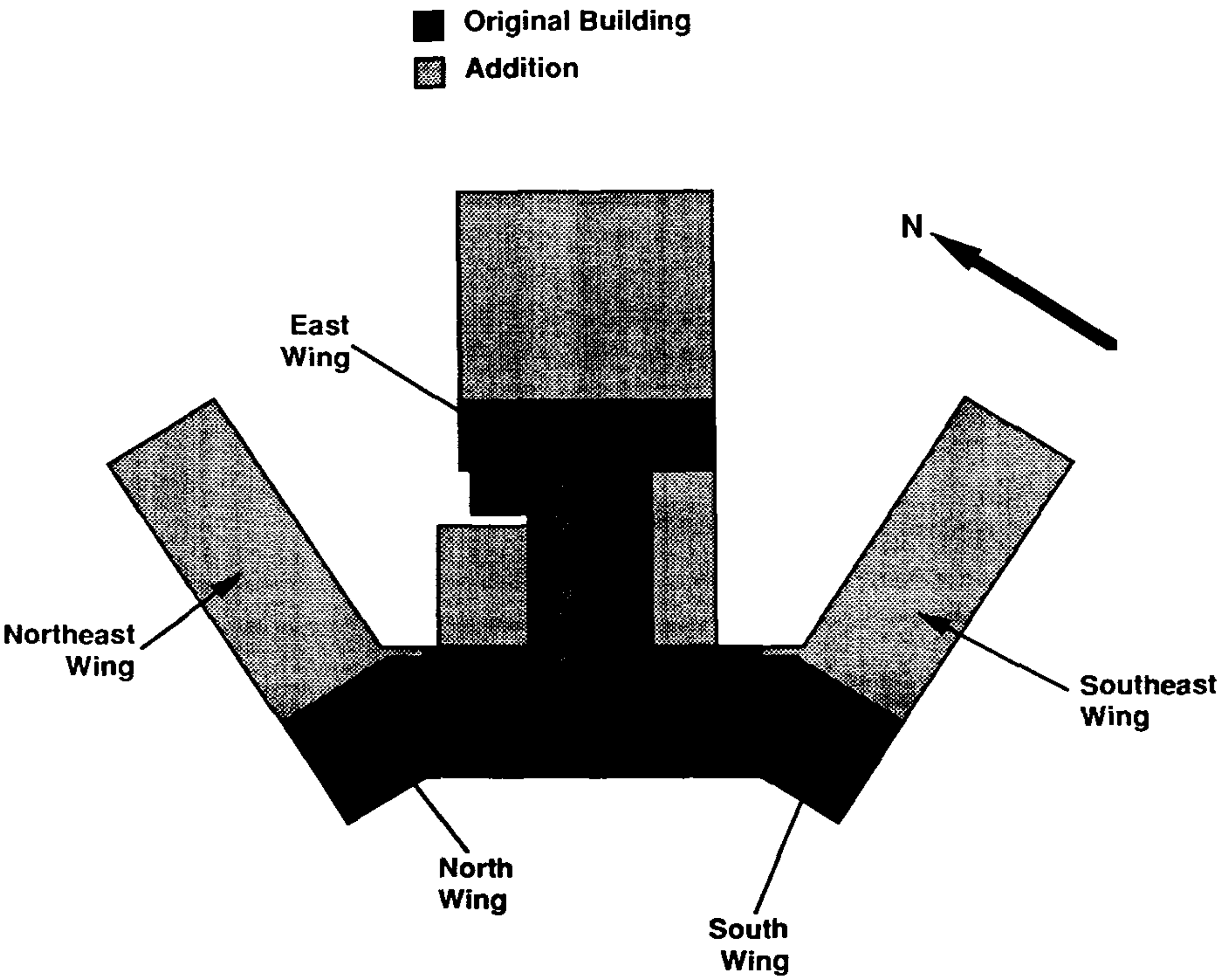

Figure 1. Greely Hall Building Layout.
Ft. Huachuca Army Base
Ft. Huachuca, AR
88-369