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VENTILATION AND EXHAUST AIR REQUIREMENTS FOR HOSPITALS— PART I: STANDARDS

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ABSTRACT

Standards for hospital ventilation with outdoor air were established based on the predominant view that pathogenic organisms may become airborne and are capable of causing disease when they come in contact with a susceptible host. In recent years, strong evidence has brought about the prevailing medical viewpoint that air as a route of transmission of infection in a hospital is one of the minor modes. This paper first reviews and compares ASHRAE's ventilation standards and the federal hospital construction standards generally referred to as the Hill-Burton standard. Secondly, a synopsis of prevailing medical views on airborne infection and hospital ventilation rates is presented, taken from the proceedings of conferences sponsored by the National Research Council, Department of Energy, and National Institutes of Health. Third, the results of a ventilation "classification" study conducted at a university hospital are presented to illustrate the application and comparison of ventilation rates in new hospital construction and the prospects for reduction.

ASHRAE VENTILATION STANDARD

Approved on February 16, 1973, ASHRAE Standard 62-73, "Standards for Natural and Mechanical Ventilation,"[1] defines ventilation requirements for spaces intended for human occupancy and specifies minimum and recommended ventilation air quantities for health, safety, and well being. The required ventilation is with outdoor air meeting certain maximum allowable contaminant concentrations, including particulates, sulfur oxides, hydrocarbons, nitrogen oxides, and carbon monoxide. Odor of the ventilation air is to be "essentially unobjectionable."

ASHRAE Standard 90-75, which was developed in 1975 and revised in 1980 as Standard 90A-1980, "Energy Conservation in New Building Design,"[2] mandated the use of the minimum ventilation quantities in Standard 62-73. In 1981 a major revision of Standard 62 was retitled as "Standards for Ventilation Required for Minimum Acceptable Indoor Air Quality."[1] It is noteworthy that the title contains the words "minimum acceptable." Acceptable air quality is defined as ambient air in which there are no known contaminants at harmful concentrations and with which a substantial majority (usually 80%) of the people exposed do not express dissatisfaction. National ambient air quality standards are cited and a four step procedure by which outdoor air shall be evaluated for acceptability is presented in the standard. Outdoor air requirements for ventilation are presented under two headings, smoking and non-smoking.

Table 1 presents excerpts of the ventilation requirements by ASHRAE Standard 62-73 and its later revision, Standard 62-81.[1] The building spaces chosen for display in the table are those significant to this study. Note that for nonsmoking areas the revised Standard 62-81 often specifies lower ventilation requirements, e.g., 7 cfm/person versus 10 to 20 cfm/person by the minimum requirement in Standard 62-73 for patient, waiting, and conference rooms. On the other hand, in smoking areas, the revised standard often calls for higher levels of ventilation than in the earlier standard, e.g., patient rooms and waiting rooms.

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HILL-BURTON STANDARD

Federal hospital construction standards have been mandated since 1946. The standard is entitled "Minimum Requirements of Construction and Equipment for Hospital and Medical Facilities." The Hill-Burton Act authorized the federal government to provide grants-in-aid to the states for planning and construction of hospitals. As with all such grants, the states must comply with federal regulations, and the Act provided for federal specification of general standards of construction and equipment for hospitals of different classes and different locations. The standard states that its specified minimum requirements "are considered necessary to ensure properly planned and well constructed health care facilities which can be efficiently maintained and operated to furnish adequate services." It does not infringe upon an individual state's right to impose more stringent requirements.

The Hill-Burton Standard was revised in 1979 and labeled as HRA publication #79-14500 and revised in 1981 as DHHS Publication No. HRA 81-14500.(3) Under Section 7.31, "Mechanical Requirements" are found the following:

General.

1. In view of our national concern for energy conservation, mechanical systems will be subject to special review for overall efficiency and life cycle costing including operational. The intent of this paragraph is to recognize that maximum savings can be made through implementation of a multitude of interrelated procedures which would be too numerous (and basic) to list. In most instances, a well designed system can be energy efficient at minimal added cost and at the same time provide for better patient comfort. However, it must be emphasized that energy conservation cannot be used as an argument for lessening patient care or safety.

2. Prior to completion and acceptance of the facility, all mechanical systems shall be tested, balanced, and operated to demonstrate to the owner or his representative that the installation and performance of these systems conform to the requirements of the plans and specifications.

3. Upon completion of the contract, the owner shall be furnished with a complete set of manufacturers' operating, maintenance, and preventive maintenance instructions, and parts lists and procurement information with numbers and description for each piece of equipment. He shall also be provided with instructions in the operational use of systems and equipment as required.

These statements make clear the increasing concern for energy conservation.

Table 2 provides a comparison between the Hill-Burton and ASHRAE Standard ventilation requirements for a few types of hospital spaces. The Hill-Burton requirements are specified in air changes per hour (ach) with values given for both outdoor air change rates (ventilation rate) and total air change rates. The ach values shown for ASHRAE Standards 62-73 and 62-81 are calculated from the ventilation (outdoor air) requirements shown in Table 1. The calculations are based on the estimated occupancy figures given in these standards (persons per 1000 ft^2 or 93 m^2 of floor area) and an assumed ceiling height of 10 ft (3 m).

The outdoor air ventilation rates required by the Hill-Burton and ASHRAE 62-81 Standards listed in Table 2 are in good agreement except for operating rooms and autopsy rooms. The Hill-Burton Standard gives the option of either 15 or 5 air changes per hour, but in the case of the lower value it requires 25 total air changes per hour (5 ach outdoor air and 20 ach filtered recirculation). Standard 62-81 requires outdoor ventilatio of only 1.2 ach based on an estimated occupancy of 20 persons per 1000 ft^2 or 93 m^2.

LITERATURE REVIEW

Hospital ventilation requirements are high in comparison to commercial buildings. Table 1 shows ASHRAE standards of 5 to 7 cfm/person (2.5 to 3.5 L/s·person) for nonsmoking areas of commercial buildings. For the hospital spaces shown in Table 1, the ventilation rates presented are 7 to 15 cfm/person (3.5 to 7.5 L/s·person), excluding autopsy spaces. Table 2 shows that the Hill-Burton Standard ventilation requirements for patient rooms, recovery rooms, and physical therapy laboratories are comparable to those of the ASHRAE standard.

What is the justification for these higher hospital ventilation rates and are there prospects for lowering the requirements? In an attempt to answer this question, a literature review was performed and is summarized in Chapter 2 of the Final Report(4) of this project. A few of the highlights from the literature review follow.

National Research Council Study

A blue-ribbon panel organized by the National Research Council of the National Academy of Sciences prepared a comprehensive review of the current knowledge on indoor air pollution(5) which was issued in 1980. The following are a few of the more pertinent passages from that report, which bear on the subject of hospital ventilation requirements, particularly airborne contagion:

> In the broadest sense, airborne infection includes a wide range of infections disseminated in a variety of ways and reaching many animal and vegetable species. In the category of human infections transmitted from person to person indoors, we place most of the acute viral respiratory infections (influenza and common colds); the viral diseases of childhood such as measles, mumps and chickenpox; primary pulmonary tuberculosis; and a scattering of infections caused by other microorganisms. Smallpox, which has now been eradicated, need not be considered further.
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> Pathogenic+ organisms may become airborne if water from a tank or reservoir is nebulized. Ordinarily the organisms are not pathogenic, but outbreaks of Legionnaires' Disease have been traced to contaminated water in the cooling towers and evaporative condensers of air conditioning systems. Legionellosis is not contagious since it is not transmitted by close person to person contact, but it is airborne and is usually acquired indoors.
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> Fungus diseases of the respiratory tract, such as historplasmosis, arise from non-human sources and may be acquired indoors or outdoors. Infection outdoors implies that the source produces huge numbers of airborne organisms so that the chance of inhaling a quantum of infection exists in spite of the enormous dilution factor.
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> Nosocomial* infections in hospitals have not been shown to be primarily airborne, and such organisms as staphylococus and streptococus and gram-negativeo bacilli are not characteristically transmitted by air. Nevertheless, nosocomial infections of the lower respiratory tract are presumptively airborne since inspired air is the most likely vehicle for carrying organisms to the lungs. Hospital patients are often hypersusceptible to infection, and transmission may occur in ways not often seen in the general population. Microorganisms in indoor air may cause allergic manifestations in sensitive people. Such illnesses are not contagious.
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> Control of epidemic spread of airborne contagion requires that each infectious case beget, on the average, no more than one new case. The concentration of infectious droplet nuclei must be reduced to the point where susceptible people stand but a small chance of inhaling an infectious particle. In relatively air tight buildings where the capacity of the ventilating system, the fraction of fresh air make-up, and the efficiency of the filters are known; where the number of infections in each generation of an epidemic is available from records; and where the pulmonary ventilation and duration of exposure of the occupants can be estimated; the essential parameters of airborne contagion can be dealt with quantitatively. In the 1974 measles epidemic in a school near Rochester, New York, this was done. During the first generation, the number of infectious particles (quanta of infection) produced per minute by the index case turned out to be 93, an amount that produced a concentration in recirculated air of 1 per 5.17 cubic meters. Twenty-six susceptible children breathing this sparsely infected air acquired measles and appeared as cases in the second generation. Such calculations provide architects and engineers with

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+Pathogenic - giving origin to disease; pathogen - any disease-producing microorganism.

*Nosocomial - pertaining to or originating in a hospital.

oGram-negative - a broad classification of bacteria according to color produced in a staining test. Staphylococus and strepococus are gram-positive.

an appreciation of the particulate nature and the quantitative aspects of a characteristic airborne infection.

Conceptually the simplest way to rid the air of infectious particles is to increase fresh air ventilation. This is the air hygienist's application of the old axioms: the solution to pollution is dilution. A second way to rid air of infection is to filter out the infectious particles. This is possible, but since droplet nuclei are in one to three micrometer size range, a good filter is required. Standard filters used in ventilating systems take out less than 30% of the small respirable particles. A third method is electrostatic precipitation of airborne particles. A fourth possibility is the use of glycol vapors. These were tried in the 1940's and found to be difficult to manage because they required exact control of humidity. A fifth possibility is germicidal ultraviolet (UV) radiation, produced by mercury vapor discharge tubes. Modern germicidal tubes can be made of glass that blocks radiation in the ozone producing range but transmits the germicidal rays of 254 nm wave length. This radiation is extraordinarily effective in disinfecting most pathogenic airborne bacteria and viruses provided the relative humidity does not exceed 70%.

Conclusions and recommendations from the NRC study(4) are:

The practice of forced air heating and air conditioning grew up to provide indoor comfort without awareness by physicians and health officers that reduced fresh air make-up increases the hazard of airborne contagion. Whatever the reason, air disinfection is seldom employed even in hospitals where hypersusceptible patients may be in close proximity to others who are sources of infection. Of all the sources of indoor airborne infection, people with respiratory infections are the most important. They are contagious and constitute the greatest hazard to others.

A need exists for professional and governmental organizations to establish a model code for indoor air quality that would meet health, energy and economics criteria. In general, the public is not aware of the distinction between ventilation control and indoor air quality control. It is our recommendation that the techniques for air quality control, including ventilation, be described in clear and consistent language. Further, responsibility for enforcement of acceptable control of indoor air quality should be defined for the various building categories. Enforcement procedures should be considered for purposes of building code construction and for building operation.

International Working Conference

The results of a broad-based literature survey, panel evaluation, and international working conference on "Hospital Ventilation Standards and Energy Conservation," sponsored by the U.S. Department of Energy, were reported in 1978.(7) A major conclusion was that present hospital standards, as exemplified by the Hill-Burton Act, are extremely conservative and difficult to justify on the basis of available knowledge and may constrain opportunities for energy conservation; however, there does not appear to be an adequate research base for the development of criteria on which overall revisions of these standards could be based.

The international working conference(6) demonstrated that a number of engineering changes have occurred in the design and operation of hospital HVAC systems to reduce energy consumption. Changes that do not in themselves alter the quality of the indoor air, i.e., affect the quantity of ventilation air used, include:

- Use of low-pressure air distribution systems
- Limited use of reheat or dual-duct mixing systems and wide use of variable air volume systems for individual room temperature control
- Use of waste heat recovery and economizers for cooling
- Decrease of design hot water temperatures to permit more opportunity for energy recovery
- Use of computer-controlled energy management systems

- Special treatment of energy-intensive heat sources such as computers, kitchens, laundry, sterilizers, etc.

A second strategy for energy conservation, the conference report continues,(6) is through a systematic reassessment of hospital ventilation standards. The following additional schemes would tend to alter the quality of the environment and, thereby, could have an adverse effect on the health and well-being of patients and staff:

- Reduce air circulation rates
- Reduce outside air requirements
- Use higher efficiency air cleaning equipment and increase the use of recirculated air(8)
- Reduce building temperatures in winter and increase temperatures in summer
- Relax humidification requirements
- Employ air-to-air energy recovery systems
- Shut down ventilation systems when not needed.

These strategies could effect the indoor air environment in four general areas.

- Biological agents, as regards hospital-acquired infections and air hygiene
- Low-level chemical contaminants from sources within the hospital, including toxic anesthetic gases, as well as outside air pollutants, both gaseous and particulate.
- Thermal properties, i.e., dry-bulb temperature, wet-bulb temperature, mean radiant temperature, and air velocity.
- Aesthetic properties, i.e., "fresh" versus "stale" versus "dead" air, including consideration of odors, air ions, and the efficacy of deodorizing techniques and air fresheners.

The international working conference and its panel went on to develop position statements and recommendations. The position statements, made by one or more panelists, reflect the state of knowledge and were not seriously challenged by another panelist or an observer. The recommendatons were intended for consideration as possible research projects. Position statements on airborne infections, odors, ventilation, and chemical pollutants and contaminants were made. A summary of those statements and the associated recommendations (in abbreviated form) are as follows(7):

AIRBORNE INFECTIONS

Position Statement -It is widely recognized that airborne bacteria are capable of causing infections. However, the majority of postoperative infections are caused by the patient's endogenous* flora and by contact infection with exogenous+ bacteria. In an overall analysis of hospital-acquired infections, valid conclusions are difficult to establish concerning the effect of ventilation on infection rates. Many studies strongly indicate that some infections are due to airborne dispersal from identified carriers, but other experiments suggest the role of airborne versus contact transmission in hospital-acquired ward infection is of minor consideration, with the exception of tuberculosis and some virus infections.

Recommendations -A possible approach to minimizing exogenous infections in the operating room may be to request the use of tightly woven gowns, in lieu of extreme ventilation rates. Generally, barrier techniques to minimize skin shedding should

*Endogenous -growing from within; developing or originating within the organism.

+Exogenous -growing by additions to the outside; developed or originated outside the organism.

be further investigated. More information is needed on the mechanisms by which gram negative organisms colonize in the upper respiratory tract; i.e., is air the source? Information is needed on the mechanisms by which viruses are spread i.e., viruses causing upper respiratory tract infections. Should these patients be isolated in single-bedrooms with an airlock and separate ventilation, or in only single-bedrooms? Perhaps isolation of some of these patient categories is not needed.

ODORS

Position Statement - Odors are usually a point source problem and should be controlled on that basis rather than setting basic ventilation rates to dilute odor below their thresholds. When considering reduced ventilation rates, odor detection can become a major factor. The increased percentage of people who can begin to detect specific odors as the dilution is decreased by a factor of two or four is substantial. It was agreed, however, that odorous sources such as cancer wards, laboratories, and bathrooms could be treated locally with increased filtering or diluting air, therefore not impeding reduction of ventilation rates.

Deodorizers and air fresheners should not be added to the hospital environment to control odors. These chemicals may have a temporary effect in masking specific malodors, but with extended use the pleasant smell may become associated with something unpleasant and its effectiveness will be lost. Further, these compounds increase the airborne chemical contaminant load with materials about which little is known.

Recommendations - Yaglou's work on ventilation rates needed to dilute odors needs validation in the context of today's technology and cultural factors. The sources and intensities of hospital odors need study. The emission strength of typical odor sources within the hospital must be determined before a judgment can be made about the amount of fresh air volume per minute needed to dilute the odor below threshold. Priority should be given to those studies where the response of human subjects to human odor emission is explored.

VENTILATION

Position Statement -Ventilation rates in ward areas could be reduced to those for commercial building space. This conclusion was reached from analysis of data that showed the relative minor importance of airborne contagion in hospital-acquired infections. It was also suggested that the amount of ventilation air needed to control excess build-up of humidity would be more than adequate for dilution of most of the chemical contaminants found in hospitals. The whole question of the appropriateness of recirculation of air in various areas of the hospital could and should be put to rest with a statement that it is appropriate for some areas, with identification of those areas.

Recommendations -The feasibility of creating micro-environments to satisfy particular patient environmental needs rather than creating that environment in a whole room, suite or unit should be studied. Maintenance of temperature and ventilation rates in post-surgical and isolation areas are far more critical than in the average ward or administrative office and should be more carefully maintained. Thermal comfort in general ward areas is highly individualized and could be controlled by blankets and eliminating open backed gowns. Specific humidity levels could be delivered through respiratory therapy devices to the individual patient rather than the whole room or ward. Detection of odors is also an individual matter, depending on the odor and sensitivity of the individual to that particular odor. Cancer wards which are often odoriferous could be supplied with separate carbon filters, but these would ordinarily not be necessary in regular recovery or administrative areas. Studies should be made of the special ventilation needs for critical areas such as burn units, isolation wards, and in labs where volatile chemicals are used. Research is needed to resolve the question of toilet exhaust recirculation. The feasibility of varying ventilation rates with activity over a 24-hour cycle should be studied and ventilation standards should be developed which would apply under emergency conditions of severe energy shortage.

CHEMICAL POLLUTANTS

Position Statement -It was suggested that the U.S. National Ambient Air Quality

Standards be considered as adequate for application to patient care areas. This was not disputed nor was it particularly supported. There was some agreement, however, that the one-tenth of the time-weighted-average, Threshold Limit Values, for chemical contaminants, as specified by ASHRAE Standard 62-73, was completely inappropriate for the continuous exposure experienced by patients.

Recommendations -The extent of hospital pollution from each of the following sources should be studied: a) Penetration from outside; b) Background emission from construction materials (off gassing properties of building materials; c) Emission from humans, and d) Emission from processes such as solvents used in pathology and histology.

CHEMICAL CONTAMINANTS

Position Statement -The diversity of cleaning products and cleaning methods should be decreased with use of those that minimize the need for outside air. Hospital housekeeping functions are carried out daily using a variety of soaps, shampoos, furniture polishes, organic solvents, and bactericidal compounds. The amount of chemical contaminant load added to the hospital air environment is unknown, but many of these compounds are toxic, presenting severe occupational health hazards. Most hospitals are using far too many products for cleaning and disinfecting purposes and are frequently not aware of their chemical composition.

Recommendations -In general, more specific information is needed on the use of hazardous chemicals throughout the hospitals. Industrial hygiene type surveys should be carried out to inventory the chemical agents used and their residual concentrations.

The university sponsoring group developed the following five major points based on the conference recommendations, the literature, and feedback from the panelists:

1. The hospital in general is over ventilated and some reduction appears possible. However, in planning reduced overall ventilation rates, care must be taken to ensure adequate ventilation of specific micro-environments. All of the following points must be considered in the context of this position.

2. High ventilation rates have traditionally been assumed necessary in the hospital for control of airborne infections. However, current studies indicate that these are a very minor part of the overall hospital infection problem and would not be measurably affected by reduction of ventilation air to the levels under consideration. Ventilation for many areas of the hospital can probably be reduced to that of commercial office space.

3. Humidity does not need to be controlled on the basis of human comfort. Other factors should define humidity endpoints.

4. The probably limiting constraint on ventilation is control of chemical contaminants. No information exists to adequately characterize the airborne chemical load in the hospital setting at the present time.

5. The question of odor needs further research. In particular, Yaglou's work of 1936-37 needs updating in the context of today's technology and cultural factors.

The Role of Air in Hospital-Acquired Infections

Chapter 3 of the Minnesota report on the literature survey(7) provides the following comments on the role of air in hospital-acquired infections.

The acquisition of an infection involves five stages; i.e., 1) a reservoir of potentially pathogenic organisms; 2) dispersal from the source; 3) transfer through the environment; 4) deposition on a susceptible host, and 5) multiplication. Each stage is an important and essential determinant in the risk of infection. Whether the infection leads to disease depends on the properties of the organism, the susceptibility of the host and the site of infection.

Bacteria are ubiquitous and while they are relatively harmless to an individual in good health, they can be fatal for the debilitated patient such as individuals with upper respiratory infections, newborns and patients undergoing surgery. The organisms are found on an individual's hands, hair, clothing and in the nose and may be dispersed during normal activities, making control of pathogens a multifactoral problem. Most often it is impossible to determine the exact means by which a patient comes in contact with a particular organism.

Air currents of 40 -50 feet/minute and turbulences from opening and closing doors are not uncommon, so that transfer of staphylococci for considerable distances is clearly possible. In fact, aerial transfer has been demonstrated for over 90 feet. There is a considerable amount of laboratory work to show that staphylococci survive in the dried state for periods measured in days or weeks.

There are two ways airborne staphylococci or other microorganisms might infect hospital patients and personnel: 1) by inhalation, which may occur anywhere and at any time, or 2) by settling directly into some susceptible area, such as a wound, or onto instruments or dressings that subsequently come into contact with the wound.

There is no doubt that potentially pathogenic microorganisms are present in the environment, and that under certain circumstances airborne transfer can be of importance. However, along with the possibility of aerial transfer, there is also the possibility of transfer by other routes, and the existence of other factors that enhance or diminish the rate of infection. Therefore, the problem is to assess the importance of all in hospital acquired infections, in relation to other factors and to apply effective control to the most important routes which transfer the majority of the pathogens.

In 1931, William F. Wells developed an air centrifuge for examining the fine bacteria-laden particles in the air. Evidence obtained with this new tool led, in 1924, to the first presentation of the droplet nucleus theory. Droplet nuclei are the dried residues of the smallest respiratory droplets. They are in the one to three micrometer size range, disperse rapidly throughout the air of a room, and are carried wherever the air goes. Settling velocity is negligible in comparison with the velocity of air movement in occupied rooms. Organisms attached to droplet nuclei are removed from indoor air by dying, being vented to the outdoors, or being inhaled into someone's respiratory tract. Standard filters used in ventilating systems remove a small fraction. There is no reservoir of infectious droplet nuclei other than the respiratory tracts of people carrying the organisms. Wells believed that aerial transmission from person to person occurs indoors where droplet nuclei are in sufficient concentration to be a hazard. He accepted Chapin's convincing evidence that infectious contact (contagion) requires close proximity in time and space between host and victim but extended the infectious range to the walls of the room, i.e., to the confines of the enclosed atmosphere. We now know that the range of airborne contagion must be further extended to include sharing the same ventilating system if the air within the system is recirculated. The recirculating system becomes a common enclosed atmosphere.

The simple demonstration that a pathogenic organism has been deposited on a settling plate or is present upon analysis of an ... Air Sampler is insufficient evidence to implicate the air as the mode of transmission. Even if one were to show that the pathogen was more frequently found in the air than on hands of medical personnel, it still must be demonstrated that airborne transmission is the more likely mode of infection. Lidwell, 1975, and Hambraeus, 1975, studied the transfer of staphylococci unique for one patient and compared the staphylococci counts to those obtained from tracer particles. They found that the transfer of staphylococci occurred with at least 10 times more frequency than the transfer of tracer particles. The conclusion was that the number of staphylococci found elsewhere in the ward could not be accounted for by airborne transmission alone.

Thus, the role of air cleanliness with respect to infection rates has not been definitively demonstrated, nor has a suggested "threshold value" which could be correlated with infection rates been developed. Consensus is simply that the air should be kept as clean as possible.

The role of air engineering and ventilation should be placed in perspective among other risk factors. Ventilation by air under pressure tends to facilitate rather than to prevent the spread of microorganisms in a hospital. It is therefore suggested that an air system should be versatile and adjustable for specific needs rather than pursuing a course of continually more expensive overall air handling and disinfection. Until further well designed studies provide more conclusive evidence on the relative importance of airborne organisms in the transmission of nosocomial infections, infection control efforts in the general hospital should focus on the adherence to protective isolation procedures of patients with serious illnesses and for whom the airborne route may play a significant role in the transmission of disease.

Chapter 4 of the Minnesota report(7) explores the realm of indoor air quality within the hospital. Some pertinent quotes are:

> Perhaps the most important consideration for patients health is that patients have 24 hours per day exposure to the same air supply. In this respect they differ from what would be considered a normal working population. In fact, existing air quality standards and criteria are all based on the assumption that humans divide each day between two environments, the work and home.
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> A second factor to consider in determining the effects of indoor air quality on patients is that their health may be impaired in such a way that could make them more susceptible than a healthy population might be to the same air contaminants. Threshold limit values (TLV) are based on the assumption that a worker is healthy and only has a maximum eight hour per day exposure to a given chemical. The hospitalized patient may be far from healthy and has a 24 hour per day exposure to whatever substances might be in the air.
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> Sources within the hospital contribute substantially to the chemical contamination load of the hospital environment. Again, because concern over internally generated hospital contamination has tended to focus on biological agents, the literature does not contain much information on the chemical contamination of hospital air. Among those chemical contaminates cited as particularly hazardous to hospital occupants are: formaldehyde, radon, air ions, mercury, smoking, cleaning agents, toxic chemicals, and aesthetic gases.

VENTILATION CLASSIFICATION OF HOSPITAL SPACES

The foregoing literature survey should have made evident the complexity of setting ventilation standards for hospitals. Nevertheless, there is a general consensus from prior studies, particularly the Minnesota working conference, that "standard" ventilation rates could probably be reduced without increasing health risks. Hospital areas proposed for reduced ventilation rates are the relatively "clean" spaces, such as patient rooms or wards, waiting rooms, corridors, etc., as opposed to the "dirty" spaces, such as operating rooms, isolation rooms, autopsy rooms, etc. To assess the impact of reduced ventilation in these "clean" spaces, a classification study was conducted using a university hospital as a model.

Hospital Description

Completed in 1980 at a cost of about $95,000,000 the university hospital represents one of the most modern medical care facilities in the world. Its nearby location, the complete and accurate documentation of all spaces and services, and the offer of cooperation and support from Medical Center personnel made it an ideal choice as the focus of this research study.

Figure 1 is an "Exploded View" of the hospital with the nine-floor patient tower on the right side, the "ancillary section" of five floors on the left side, and the "central core." The central core routes the traffic of patients, visitors, and staff around patient care areas rather than through them. There are three bed towers providing 616 acute care patient beds and the associated nursing stations, visitor spaces, and food services. The ancillary section houses the medical and surgical support facilities including radiology, laboratories, operating rooms, emergency/trauma center, etc. Figure 2 provides a schematic representation of the third floor.

All exterior glass is solar-tinted and double-paned. Walls are heavily insulated. Space heating, water heating, and a portion of the air conditioning utilize steam generated by the university's steam plant. Heating, ventilating, and air-conditioning systems are zoned to allow the minimum size of equipment to handle the load due to multiple sun exposures per zone. Air-handling systems are designed and computer controlled to allow use of recirculated and/or outside air for maximum energy efficiency. Emergency generators can be used to reduce peak demands in order to minimize the effect of peak load charges for power. An automated transport system for soiled linen and trash is provided at key locations on every floor to eliminate manual handling and circulation of these items through the building. A central vacuum cleaning system is provided. The building has a computerized automation system to control and monitor mechanical, electrical, and special systems, including the fire alarm and life saving system for the building.

Classification Method

A principal objective of this study was to "classify indoor spaces according to their ventilation requirements and identify the opportunities and information requirements for reduced exhaust air rates and ventilation." Discussions with Medical Center personnel responsible for the operation and health safety of the hospital's environmental conditions, made clear that there is a large cubage of "good" or "clean" spaces in a modern complex. As Table 2 shows, the Hill-Burton Standard specifies outdoor air changes and total air changes based on the type of hospital space. It is of interest, therefore, to examine hospital spaces according to their need for ventilation, i.e., fresh outdoor air. Such a classification of space according to need for ventilation places the code requirements in perspective relative to the large cubage of undesignated or "clean" spaces.

The following classification system for hospital spaces, according to ventilation requirements, was developed:

1. Dirty. The air cannot be recirculated from such spaces due to contamination by noxious odors, toxic chemicals, virus or pathogenic bacteria or other microorganisms that could cause serious alergic reactions in sensitive and sick persons.

2. Moderately Dirty. The air is contaminated with dust, tobacco smoke, unpleasant odors, nontoxic chemical vapors, or other annoying substances. The air may be recirculated if suitably diluted with "fresh" air or treated through filters, activated charcoal, or other odor-removing chemicals, ultraviolet light, or other suitable processes to reduce the contaminant level to that satisfactory for health safety, odor control, or other established criteria.

3. Clean. The air may be recirculated without any unusual treatment beyond the normal filtration and dilution with outside air of an air conditioning system designed to "office" building standards.

In cooperation with Medical Center consultants, the above ventilation classification scheme was applied to spaces in the model hospital. All dirty and moderately dirty spaces were visited to obtain familiarity with the types of contaminants, the use of the rooms, the reactions of persons who work there to the air quality in the room, and any special precautions taken.

Central Core

The central core of the hospital is a nine-story circular tower serving the vertical transportation and other pedestrian and patient traffic links between the bed towers and the ancillary building, as illustrated in Figure 1 and Figure 2. This core area was selected for the first ventilation classification study for two reasons; first, it was readily accessible and represented a large area very similar to the "clean" spaces in commercial buildings, and, second, most of the area was served by a single air-handling unit, which could be easily assessed for energy conservation potential.

Using architectural floor plans, computer printout sheets listing room areas, and HVAC drawings and equipment specifications, Table 3 was prepared. The table has three major column entries into which all spaces in the core are classified. The three classifications are for "Dirty and Moderately Dirty Spaces," "Clean Spaces," and "Non-Conditioned" spaces.

The only dirty or moderately dirty spaces in the core are toilets, toilet vestibules, and a morgue and morgue holding rooms. Table 3 shows that these spaces constitute only 10% of the total floor area in the core section. If nonconditioned spaces (primarily elevator shafts and stairwells) are excluded, then the dirty and moderately dirty spaces constitute 12.4% of the "conditioned" floor area in the core.

Air-handling unit (AHU) 24, which serves the core area of the hospital, provides air change rates as shown under "Designed Values" in Table 4. Eight air changes per hour (ach) are delivered to the "clean" spaces in the core section of which 2 ach are outside or fresh-air ventilation. Exhaust through the public toilets is at a rate just under 10 ach.

Table 4 compares the ventilation air rates for the core section as designed and those recommended or required by three Standards. It will be readily observed in this table that the designed ventilation air change rates and toilet exhaust conform to the 1979 Hill-Burton Standard.(3) It is of interest to note that ASHRAE (Ventilation) Standard 62-73(1) would have required more than three times the ventilation rate used in the design. Hospital foyer and hallways by that standard required a minimum of 20 cfm/person, and gave an estimated 50 persons per 1000 square feet of floor area (see Table 1). This requirement would result in 36,834 cfm ventilation rate for the core section of the hospital or 85% outside air. ASHRAE Standard 90-75 and 90A-1980(1) "Energy Conservation in New Building Design," reference the minimum values of ventilation from Standard 62-73; thus application of that standard to the core would also call for the 36,834 cfm of fresh air.

ASHRAE Standard 62-81,(2) which replaced 62-73, does not list a hospital space appropriate to the core. The values of 5 cfm/person and 15 cfm/person for nonsmoking and smoking areas, respectively, listed in Table 5 are for hotel/motel lobbies (see Table 1). This was considered the "best" fit to activity in the core section of the hospital. Lobbies, foyers, and lounges for theaters and lecture and concert halls require a somewhat higher 7 and 35 cfm/person for nonsmoking and smoking areas.

Using the estimated occupancy level of 50 persons per 1000 ft^2 for hospital foyers and hallways (Standard 62-73) the minimum ventilation requirement by ASHRAE Standard 62-81 is 9,209 cfm for nonsmoking conditions and 27,625 cfm if smoking is permitted. This latter figure is also well above the 11,000 cfm requirement of the Hill-Burton Standard.

The lower part of Table 4 lists the exhaust air requirements for public restrooms. Again it can be seen that the design rate of toilet exhaust is almost equal to the 10 air changes per hour specified by the Hill-Burton Standard (1979). The minimum requirement by ASHRAE Standard 62-73 (and hence by ASHRAE Standards 90-75 and 90A-80) is 15 cfm/person, which, with a listed estimated occupancy of 100 per 1000 ft^2, results in 7827 cfm. This is identical to the Hill-Burton Standard requirement.

ASHRAE Standard 62-81 lists its ventilation requirement for public toilets as 75 cfm per stall or urinal. This results in a ventilation or exhaust air rate of 8100 cfm for a total count of 108 stalls and urinals in the core section.

Table 5 presents the results of a computer simulation(9) for estimating the annual energy consumption and cost savings by two ventilation energy-conservation measures. Using a heat exchanger to transfer heat between the exhaust air and fresh ventilation air, and assuming a 50% overall effectiveness in the exchange, a saving of $4,798 or 44% of base case annual energy cost results. By reducing the ventilation rate from 11,000 cfm to 7440 cfm (the toilet exhaust rate) a savings of $3,323 or 30% of base case energy cost is made.

Patient Bed Tower

Table 6 provides a classification of spaces for the first three floors only of Patient Bed Tower 1. As in the core section, the classification is for "Dirty and Moderately Dirty" spaces, "Clean" spaces, and "Non-Conditioned or Exhausted Only" spaces. Dirty and moderately dirty spaces are almost exclusively isolation care rooms, patient toilets, and soiled utility spaces. Floor 1 devotes about 50% of its area to conference room, office, and associated circulation space for the hospital staff and visiting medical personnel. The other 50% is mechanical room space housing air-handling units, electrical panels, soiled and waste products, etc. Floor levels 2 to 8 are patient care. As can be seen in Table 6, the dirty areas for levels 2 and 3 (typical of all) are again primarily toilets. One isolation room and vestibule on each level serves for patients with communicable disease.

Table 7 is a summary of the classification of spaces for all eight floors of Tower 1. Of the total of 91,224 ft^2 of floor area in this tower, 10,658 ft^2 or 11.5% of the area is dirty space equipped with exhaust. Most of this dirty space (75%) is toilet area. The clean areas (73,575 ft^2) consist of patient rooms (excluding toilet and shower), circulation and reception spaces, and nurses station and supporting service areas. These clean areas constitute 86% of the space on all floors except Level 1. The toilet areas are typically exhausted at the rate of 10 ach, in accordance with existing ASHRAE standards. This ventilation rate is maintained primarily for odor control. At the bottom of Table 7, the total toilet space is shown as 8,000 ft^2 and the exhaust through these toilets as 13,940 cfm. This results in 10.5 ach, in agreement with the Hill-Burton standard requirement of 10 ach.

In Table 8 the design air change rates for Patient Tower 1 are summarized. It will be observed that the minimum outside air ventilation rates are 2.2 ach to the patient rooms on the periphery of the tower and 1.85 ach to the nursing and service areas in the central portion of the tower. These average out at a little over 2 ach as required by the Hill-Burton Standard.

ASHRAE Standard 62-81 specifies minimum ventilation rates of 7 cfm/bed and 35 cfm/bed for nonsmoking and smoking conditions in patient bedrooms. For floors 2 to 8 there are 32 rooms per floor or 224 rooms total. This would require 1568 cfm nonsmoking and 7840 cfm smoking. For toilets, Standard 62-81 specifies 50 cfm/room, which is the designed value. This would require 11,200 cfm and that corresponds exactly to the toilet exhaust air rate for the patient rooms as shown in Table 8.

SUMMARY

The current knowledge of health related aspects of ventilation, particularly in hospitals, has been a subject of national and international panels and conferences.[5-7] The predominant view is that infectious agents are airborne and move from one part of a hospital to another with the air. The airborne bacteria are capable of causing disease when they come in contact with a susceptible host. In general, hospital patients are not only hypersusceptible hosts for infectious microorganisms, but they also are subjected to the hospital air 24 hours per day. People with respiratory infections are contagious and constitute the greatest hazard to others.

There is strong evidence and a prevailing medical viewpoint that air as a route of transmission of infection in a hospital is one of the minor modes. It is well recognized that contact transmission is a far more predominant mode of infection. It is suggested, therefore, that a study be made of the feasibility of creating microenvironments to protect against infections and satisfy particular patient needs, rather than creating that environment in a whole room or section of the hospital. Also recommended for consideration are the use of tightly woven gowns, filtering of the air to remove droplet nuclei in the one to three micrometer size range, and the use of glycol vapors and ultraviolet radiation to reduce infectious particles in the air in lieu of excessive dilution by fresh air ventilation. Additional research will be necessary to establish the ability to control indoor air quality and health risk through these methods.

Indoor air quality in a hospital has additional and, perhaps, just as important problems with chemical pollution and noxious odors. Evidence has been presented that most hospitals are using far too many products for cleaning and disinfecting purposes. The amount of chemical contaminant load that use of these products adds to the air is unknown, but many are toxic, presenting severe health hazards. Hospitals have numerous odor sources of varying intensities. Dilution by outside air is the current major method of control. Much of the odor is generated from point sources and could be controlled locally with increased filtering or diluting air without a general increase of ventilation rates.

For the core section of the university hospital, which serves as the vertical transportation and connecting area between the patient bed tower and the medical treatment ancillary unit, the design ventilation (outside air) rate was 2.0 air changes per hour, in conformance with the 1979 Hill-Burton Standard. For air-handling unit 24, which serves some 42,000 ft^2 of the core area, the ventilation rate is 11,000 cfm at 2.0 air changes per hour. ASHRAE Standard 62-81 would require 5525 cfm for nonsmoking conditions (5 cfm/person) and 16,575 cfm for smoking conditions (15 cfm/person) at an estimated peak occupancy level of three persons per 100 square feet. Thus 11,000 cfm would appear to be a reasonable ventilation rate at peak occupancy when considering the chemical contaminants and high cleaning agent usage in hospitals.

The required total toilet exhaust air rate for the core section is 7800 cfm based on the Hill-Burton Standard, or 8100 cfm based on ASHRAE Standard 62-81. Thus, the toilet exhaust may not be the determining factor for the fresh ventilation air supply, at least during high occupancy periods. During the nighttime or other periods of low-occupancy, however, it should certainly be possible to reduce the ventilation rate. Using a simplified method for calculating building energy usage, developed by ASHRAE Technical Committee 4.7, reducing the ventilation rate by air handling unit 24 in the core section from 11,000 cfm to 7440 cfm would result in an annular cost saving of about $3300. This is a reduction of 30% from the current estimated annual energy cost for this unit.

Patient Tower 1, which has eight floors with 224 individual patient rooms, has a ventilation (fresh air) rate of 16,720 cfm and a toilet exhaust air rate of 11,200 cfm. Again, the toilet exhaust air rate, based on 50 cfm per toilet, is not the controlling factor for ventilation. Rather, it is the 2.0 ach of outside air ventilation required by the Hill-Burton Standard. Using ASHRAE Standard 62-81 as the ventilation criteria, the requirement would be 1568 cfm nonsmoking (7 cfm/bed) and 7840 cfm smoking (35 cfm/bed). Thus the 2 ach requirement of Hill-Burton leads to an excessive ventilation rate, double that required for smoking conditions and over 10 times the rate for nonsmoking conditions. There is a considerable potential for reduced ventilation rates in the patient tower, provided that chemical and cleaning agent contaminate levels were kept within safe health limits and tolerable odor levels.

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TABLE 1

ASHRAE Standards for Ventilation

BUILDING TYPE Room Designator	Standard 62-73			Standard 62-81		
	Persons* 1000 ft2	Minimum cfm/per	Recommended cfm/per	Persons* 1000 ft2	Smoking	Nonsmoking
HOTELS, MOTELS, RESORTS					cfm/(+)	cfm/(+)
Bedrooms	(5)	7	10-15	(5)	30(rm)	15(rm)
Baths, toilets		20	30-50		50(rm)	50(rm)
Lobbies	(30)	7	10-15	(30)	15(per)	5(per)
Conference Rm.	(70)	20	25-35	(50)	35(per)	7(per)
PUBLIC RESTROOMS	(100)	15	20-25	(100)	75(stall)	-
CORRIDORS	(5)	5	7-10		0.02(SF)	
OFFICES					cfm/per°	cfm/per°
Gen'l. Office Space	(10)	15	15-25	(7)	20	5
Waiting Rooms	(30)	10	15-20	(60)	35	7
HOSPITALS						
Foyers, Hallways	(50)	20	25-30			
Patient Rooms	(15)	10	15-20	(10)	35	7
Operating, Delivery		20	-	(20)	-	40
Recovery, Intensive Care		15	-	(20)	-	15
Physical Therapy	(20)	15	20-25	(20)	-	15
Autopsy	(10)	30	40-50	(20)	-	100

*Estimated occupancy levels in persons per 1000 ft^2 (93 m^2) of floor area.

+In general Standard 62-81 presents ventilation quantities in cfm/person (per); however, some entries are in dfm/room (rm), cfm/toilet stall-urinal (stall), and cfm/ft^2 of floor area (SF).

°Values in L/s·person are one-half of the table values.

TABLE 2

Comparison of Ventilation Standards for Hospitals

Area Designation	ASHRAE Std. 62-73 Estimated Occupancy	Min. ACH[1]	Rec'd ACH[1]	ASHRAE Std. 62-81 Estimated Occupancy	NonSmoke ACH[1]	Smoking ACH[1]	'79 & '81 Hill-Burton Std. Outdoor ACH	Total ACH	Recircu-lation
Operating Rooms	(20)[2]	2.4		20	4.8		5/15	25/15	Yes[3]
Recovery Rooms	(20)[2]	1.8		30	1.8		2	6	Yes[3]
Patient Rooms	15	0.9	1.4-1.8	10	0.4	2.1	2	2	Optional
Physical Therapy	20	1.8	2.4-3	20	1.8		2	6	Optional
Autopsy	10	1.8	2.4-3	20	12		2	12	No
Toilet Rooms	100[4]	9	12-15	100[4]	10	10	Optional	10	No

Notes: [1]Outdoor air changes per hour based on estimated occupancy in persons per 1000 ft^2 (93 m^2) and a 10 ft (3 m) ceiling height (ventilation rates from Table 1).

[2]Estimated occupancy from Standard 62-81, none given for Standard 62-73.

[3]"If the total ACH of 25 ACH includes 5 ACH of OA, then 20 ACH may be recirculated if filtered in this fashion: 2 filter beds, #1 = 25% and #2 = 90%."

[4]Estimated occupancy and ventilation requirements are for hotel or institutional toilets; no values are given for hospital toilets in the standards. The values here are exhaust air requirements as opposed to outdoor ventilation.

TABLE 3

North Hospital
Classified Floor Areas
"Core" Section*

Floor Level	Dirty & Moderately Dirty: Identification No.	Name	Area ft²	Exhaust cfm	Clean Spaces: Identification No.	Name	Area ft²	Nonconditioned or Exhausted Only: Identity	Area-ft²
00	1	Morgue-Holding	123	80		Circulation	2897	Elevators (4)	227
	1A	Morgue-Viewing	163		602	Uniform	768	Elev. pits (5)	355
	2T1	Toilet	137	230	4	Mailroom	227	Stairwell	148
	2T2	Toilet	136	220	611	Conference Rm	300	Other	125
Subtotal		(9.9%)	559	530		(74.9%)	4212	(15.2%)	855
0T*	0T1	Toilet	137	150		Circulation	4783	Elevators	417
	0T2	Toilet	150	150				Stairwell	266
								Shop Facility	3283
Subtotal		(3.2%)	287	300		(52.9%)	4783	(43.9%)	3966
01*	0T1	Toilet	208	330		Circulation	2675	Elevators (9)	436
	0T2	Toilet	217	340	0A	Cargo Lobby	216	Stairwell	181
					0B	Storage	85		
Subtotal		(10.6%)	425	670		(74.1%)	2976	(15.4%)	617
02*	0T1	Toilet	208	280		Circulation	2728	Elevators (9)	436
	0T2	Toilet	217	300	0A	Cargo Lobby	216	Stairwell	116
	0T3	Toilet	225	330	0B	Maint-Storage	85		
	0T4	Toilet	252	340					
Subtotal		(20.1%)	902	1250		(67.6%)	3029	(12.3%)	552
03*	0T1	Toilet	208	330		Circulation	2728	Elevators (9)	436
	0T2	Toilet	217	340	0A	Cargo Lobby	131	Stairwell	116
					522	Patient Transf.	176		
					0B,C,D	Storage	164		
Subtotal		(10.2%)	425	670		(76.6%)	3199	(13.2%)	552
04	0T1	Toilet	208	330		Circulation	2728	Elevators (9)	436
	0T2	Toilet	217	340	0A	Cargo Lobby	216	Stairwell	116
						Mechanical	85		
Subtotal		(10.6%)	425	670		(75.6%)	3029	(13.8%)	552
05	0T1	Toilet	208	330		Circulation	2728	Elevators (9)	436
	0T2	Toilet	217	340	0A	Cargo Lobby	216	Stairwell	116
		Vestibule	35		5501 & 5502		449		
						Mechanical	97		
Subtotal		(10.2%)	460	670		(77.5%)	3490	(12.3%)	552
06	0T1	Toilet	208	330		Circulation	2728	Elevators	436
	0T2	Toilet	217	340	0A	Cargo Lobby	216	Stairwell	116
		Vestibule	35			Mechanical	85		
Subtotal		(11.4%)	460	670		(75.0%)	3029	(13.7%)	552
07	0T1	Toilet	208	330		Circulation	2728	Elevators	436
	0T2	Toilet	217	340	0A	Cargo Lobby	216	Stairwell	116
						Mechanical	85		
Subtotal		(10.6%)	425	670		(75.6%)	3029	(13.8%)	552
08	0T1	Toilet	208	330		Circulation	2728	Elevators (9)	436
	0T2	Toilet	217	340	0A	Cargo Lobby	216	Stairwell	116
						Mechanical	85		
Subtotal		(10.6%)	425	670		(75.6%)	3029	(13.8%)	552
09	0T1	Toilet	208	330		Circulation	2728	Elevators (9)	436
	0T2	Toilet	217	340	0A	Cargo Lobby	216	Stairwell	116
						Mechanical	85		
Subtotal		(10.6%)	425	670		(75.6%)	3029	(13.8%)	552
Totals		(10.0%)	5218	7440		(71.0%)	36834	(19.0%)	9854

*A few spaces in the "core" not served by air-handling unit 24 are not listed.

TABLE 4

North Hospital Core Section
Designed vs. Standard Ventilation Rates

	Designed Values	Hill-Burton Std. 1979	ASHRAE Std. 62-73 Min*	ASHRAE Std. 62-73 Rec'm'd	ASHRAE Std. 62-81 Non-smoking	ASHRAE Std. 62-81 Smoking
CLEAN SPACE						
Vol = 331,506 ft^3						
Area = 36,834 ft^2						
A. Total Air Changes						
Air Quantity - cfm	43,880	22,100[1]				
(L/s)	(20,710)	(10,430)				
ACH	8.0	2.0[1]				
B. Outdoor Air Changes						
Standard Requirement						
cfm/pers			20[2]	27.5[2]	5[3]	15[3]
(L/s-pers)			(10)	(13.7)	(2.5)	(7.5)
ACH	2.0	2.0[1]				
Air Quantity @ 0.05 Pers/ft^2						
cfm	11,000	11,000	36,834	50,647	9,209	27,625
(L/s)	(5,190)	(5,190)	(17,385)	(23,905)	(4,350)	(13,040)
@ 0.03 Pers/ft^2						
cfm	11,000	11,000	22,100	30,388	5,525	16,575
(L/s)	(5,190)	(5,190)	(10,430)	(14,343)	(2,608)	(7,823)
DIRTY SPACE (Public Toilets)						
Vol = 46,962 ft^2						
Area = 5,218 ft^2						
Exhaust Air Rates:						
ACH	9.5	10.0				
cfm/pers.			15	22.5[4]		
(L/s-pers.)			(7.5)	(11.8)		
cfm/stall-urinal					75	75[5]
(L/s-stall)					(37)	(37)
Air Quantity:						
@ 0.10 pers/ft^2 & 108 stalls or urinals						
cfm	7,440	7,827	7,827	11,740	8,100	8,100
(L/s)	(3,512)	(3,695)	(3,695)	(5,540)	(3,823)	(3,823)

Notes:

(1) As specified for "Patient Corridor"
(2) As specified for "Hospital Foyer/Hallways"
(3) As specified for "Lobbies" under the heading Hotels/Motels
(4) As specified for "Public Rest Rooms" under the heading Offices
(5) As specified for "Public Rest Rooms" under the heading Public Spaces
* Std. 62-73 "Min." values are those recommended in ASHRAE Energy Conservation Standards 90-75A and 90-81.

TABLE 5

North Hospital Core Section
Estimated Energy and Cost Savings
by Ventilation Heat Recovery and Reduced Ventilation

	Ventilation Scheme	Ventilation Rate cfm	Annual Electricity kWh	Annual Oil gal.	Electric kWh	Oil gals	Cost* $
1.	As Designed	11,000	143,166	5,800	(Base Case, annual energy cost = $10,947)		
2.	50% Efficient Heat Recovery	11,000	124,402	1,302	18,764	4,498	4,798
3.	Reduced Ventilation Rate	7,440	131,020	1,648	12,146	3,152	3,323

*Based on $0.04/kWh and $0.90/gal

TABLE 6

Patient Tower 1
Classified Floor Areas

Floor Level (AHU)	Dirty & Moderately Dirty Identification No.	Name	Area ft^2	Exhaust cfm	Clean Spaces Identification Name	Area ft^2	Noncondtioned or Exhausted Only Identity	Area ft^2
1 (26)	105T	Toilet	350	610	Circulation	1310	Stairwell	120
	107T	Toilet	285	480	Office	360	Mechanical	5821
	108	Toilet	59	-	Conference	2650	Elec. Panels	153
					Food Service	598		
Subtotal (5.9%)			694	1090	(42%)	4918	(52.1%)	6094
2	2147T	Toilet	48	50	Circulation	3135	Stairwell	144
	2152T	Toilet	50	100	Patient Rooms	4449	Custodial	37
	2101A	Recep.	34	50	Office	164		
	2145	Tub	91	120	Food Service	122		
	2153	Soil Util.	108	210	Mechan. & Elec.	203		
	Patient Rm. Toilets		1070	1630	Lounge & Recep.	349		
	Patient Iso. Rm.		147	80	Nurse Services	1395		
Subtotal (13.4%)			1548	2240	(85.0%)	9817	(1.6%)	181
(AHU 27) (10.8%)			1251		(38.5%)	4446		
(28) (2.6%)			297		(44.5%)	5138		
(31)					(2.0%)	230		
3	3146,7	Toilets	65	120	Circulation	3097	Stairwell	143
	3152T	Toilets	52	100	Patient Rooms	4466		
	3101A	Reception	32	50	Office	196		
		Tub Room	93	120	Food Service	124		
		Soil Util.	105	210	Mechan. & Elec.	208		
	Patient Rm. Toilets		923	1630	Lounge & Recep.	335		
	Patient Isolation		149	80	Support Serv's.	1434		
	(12.4%)		1419	2310	(86.3%)	9860	(1.3%)	143
(AHU 27) (9.7%)			1104		(39.1%)	4466		
(28) (2.6%)			315		(45.4%)	5183		
(31)					(1.8%)	211		

TABLE 7

Patient Tower 1
Floor Summary - Classified Areas

Floor Level (AHU)	Dirty & Moderately Dirty Identification Name	Area ft²	Exhaust cfm	Clean Spaces Identification Function	Area ft²	Non-Conditioned or Exhausted Only Identity	ft²
1	Toilets	694	1090	Circulation	1310	Stairwell	120
				Confer., Office	3608	Mech. & Elec.	5974
(AHU 26)	(5.9%)	694	1090	(42%)	4918	(52.1%)	6094
2	Toilets	1168	1780	Circul.-Rec'p.	3484	Stairwell	144
	Soiled Util.	108	210	Patient Rms.	4449	Custodial	37
	Isolation, Tub	272	250	Serv's, other	1884		
	(12.3%)	1548	2240	(86.1%)	9817	(1.6%)	181
3	Toilets	1040	1850	Circul.-Rec'p.	3432	Stairwell	143
	Soiled Util.	105	210	Patient Rms.	4466		
	Isolation, Tub	274	250	Serv's, other	1962		
	(12.4%)	1419	2310	(86.3%)	9860	(1.3%)	143
4	Toilets	1029	1850	Circul.-Rec'p.	3479	Stairwell	144
	Soiled Util.	108	210	Patient Rms.	4449		
	Isolation, Tub	272	250	Serv's, other	1926		
	(12.4%)	1409	2310	(86.4%)	9854	(1.3%)	144
5	Toilets	998	1810	Circul.-Rec'p.	3613	Stairwell	144
	Soiled Util.	135	130	Patient Rms.	4432		
	Isolation, Tub	244	220	Serv's, other	1925		
	(12.0%)	1377	2160	(86.8%)	9970	(1.3%)	144
6	Toilets	1021	1850	Circul.-Rec'p.	3484	Stairwell	144
	Soiled Util.	108	210	Patient Rms.	4449		
	Isolation, Tub	272	250	Serv's, other	1921		
	(12.3%)	1401	2310	(86.4%)	9854	(1.3%)	144
7	Toilets	1021	1850	Circul.-Rec'p.	3484	Stairwell	144
	Soiled Util.	108	210	Patient Rms.	4454		
	Isolation, Tub	272	250	Serv's, other	1714		
	(12.5%)	1401	2310	(86.2%)	9652	(1.3%)	144
8	Toilets	1029	1860	Circul.-Rec'p.	3484	Stairwell	144
	Soiled Util.	108	240	Patient Rms.	4452		
	Isolation, Tub	272	240	Serv's, other	1714		
	(12.6%)	1409	2340	(86.1%)	9650	(1.3%)	144
TOTALS	Toilets	8,000	13,940	Circul.-Rec'p.	25,770	Stairwells	1,127
	Soiled Util.	780	1,420	Patient Rms.	31,151	Mech. & Elec.	5,974
	Isolation, Tub	1,878	1,710	Serv's, other	16,654	Custodial	37
	(11.5%)	10,658	17,070	(80.7%)	73,575	(12.8%)	7,138
(AHU 27)	Periphery	7,744			31,151		
(AHU 28)	Central	1,800			36,159		

TABLE 8

Design Air Change Rates for Patient Tower 1
Floors 2 through 8

A. DESIGN DATA

1. PATIENT ROOMS (Periphery)

Total Floor Area/Volume	38,912 ft^2/350,208 ft^3
Patient Room Area/Volume	32,435 ft^2/291,915 ft^3
Toilet Area/Volume	6,477 ft^2/ 58,293 ft^3
Toilet Supply Air Rate	45,440 cfm
Minimum Ventilation Air Rate	16,720 cfm
Toilet Exhaust Air Rate	11,200 cfm

2. NURSING & SERVICE AREAS (Center)

Total Floor Area/Volume	40,954 ft^2/368,586 ft^3
"Clean" Spaces Area/Volume	38,953 ft^2/350,577 ft^3
"Dirty" Spaces Area/Volume	2,001 ft^2/ 18,009 ft^3
Toilet Area/Volume	682 ft^2/ 6,138 ft^3
Total Supply Air Rate	26,200 cfm
Minimum Ventilation Rate	10,800 cfm

B. AIR CHANGE RATES

1. Patient Rooms (Periphery)

Total for all areas	7.8 ach
Minimum Ventilation for all areas	1.85 ach
Total for "clean" spaces	9.35 ach
Minimum Ventilation for "clean" spaces	2.2 ach
Toilet Exhaust	11.5 ach

2. Nursing (Center)

Total for "clean" spaces	4.5 ach
Minimum Ventilation for "clean" spaces	1.85 ach

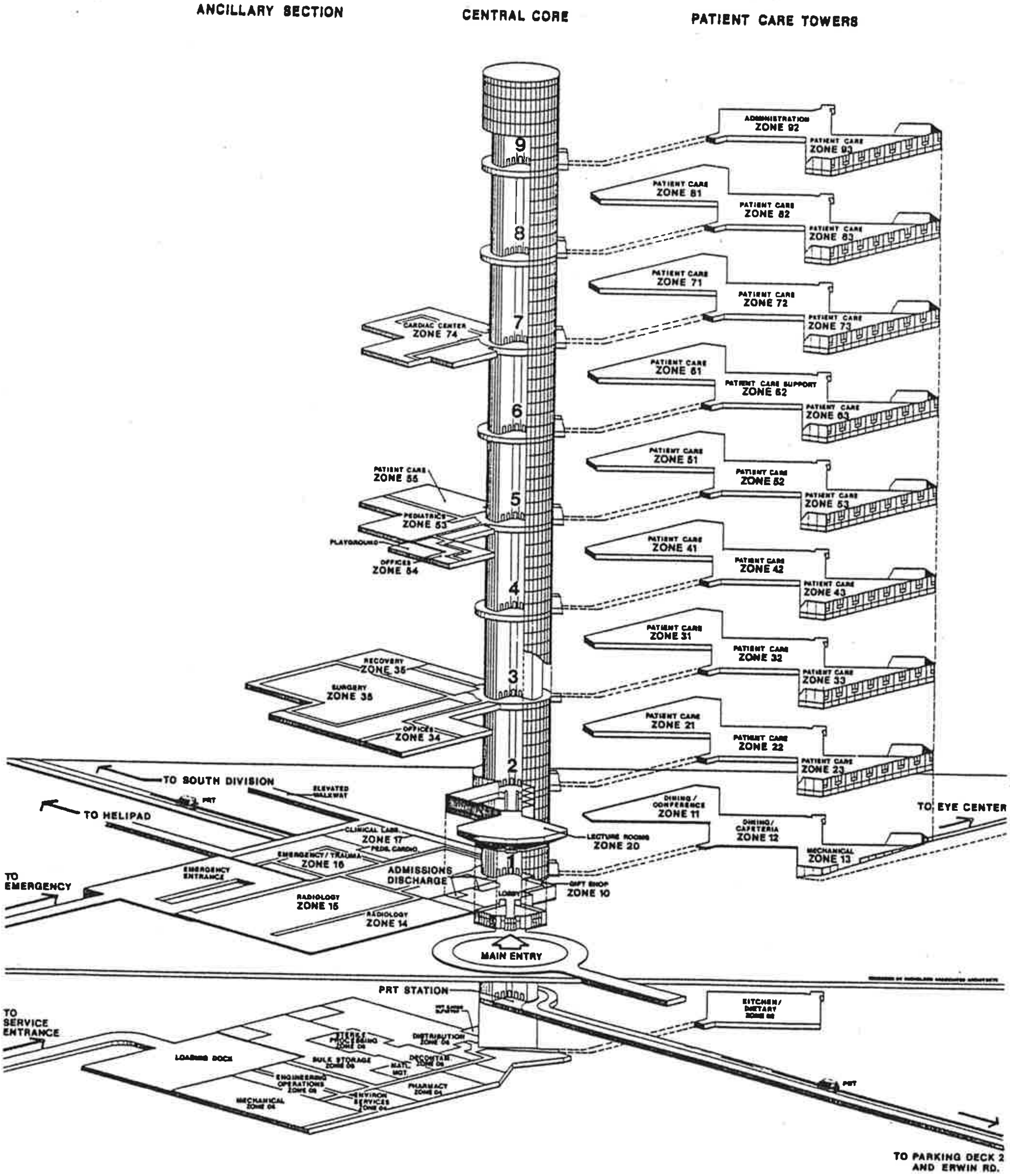
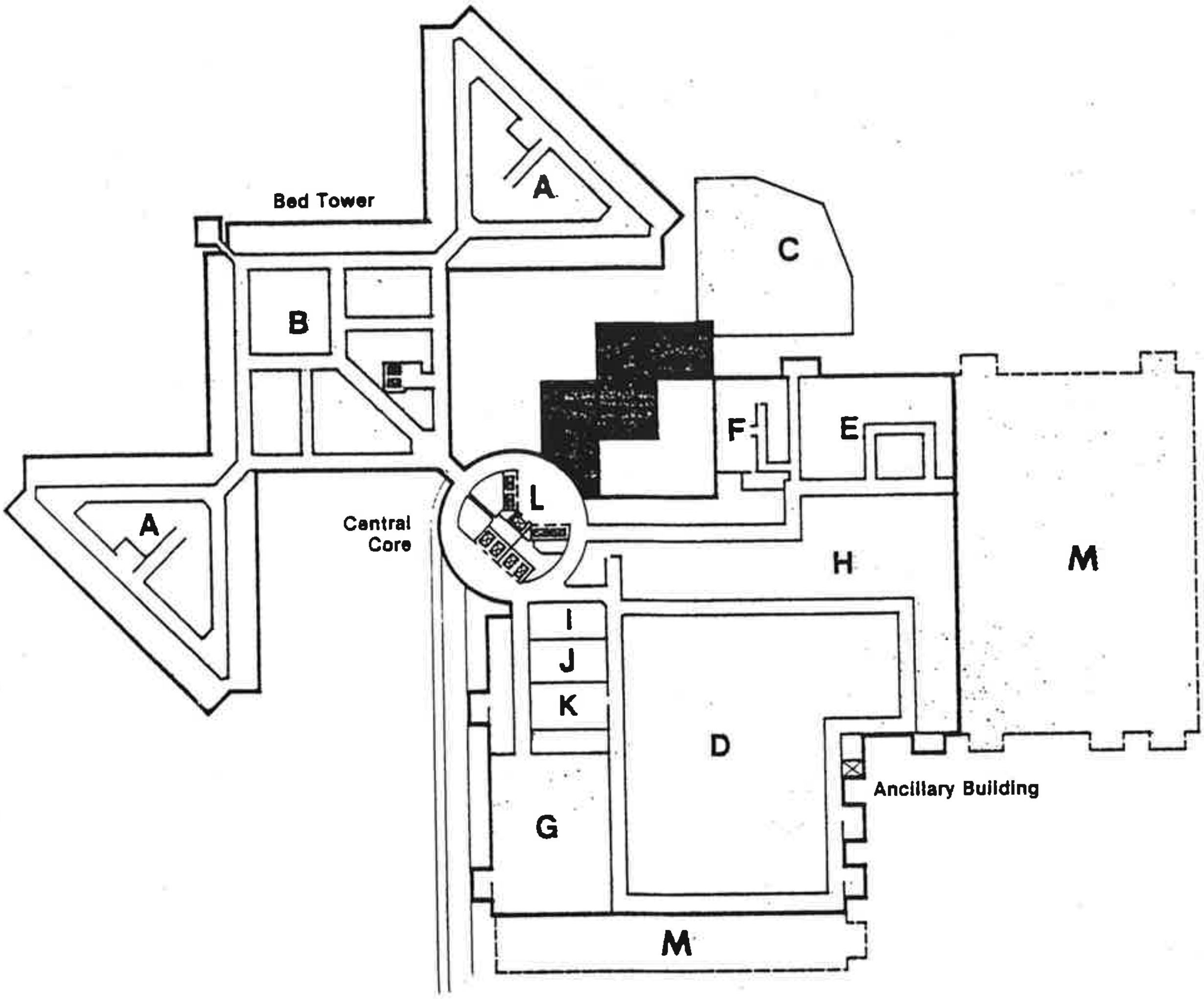


Figure 1. Exploded view of university hospital



A. 32 intermediate care surgical beds
B. 16 intensive care surgical beds
C. lecture rooms
D. surgery suite
E. Department of Surgery offices
F. Department of Anesthesiology offices
G. recovery room
H. surgical pathology laboratory
I. blood gas laboratory
J. blood bank
K. pre-operative holding area
L. central core
M. lower level roof line (available for future expansion)

Figure 2. Third-floor plan of university hospital