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Energy and Environment Division

Hospital Ventilation Standards And Energy Conservation: A Summary Of The Literature With Conclusions And Recommendations, FY 78 Final Report

Roger L. DeRoos, Robert S. Banks, David Rainer, Jonna L. Anderson, and George S. Michaelsen

September 1978

Lawrence Berkeley Laboratory University of California/Berkeley

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HOSPITAL VENTILATION STANDARDS AND ENERGY CONSERVATION:

A SUMMARY OF THE LITERATURE WITH CONCLUSIONS AND RECOMMENDATIONS,

FY 78 FINAL REPORT

School of Public Health
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Minneapolis, Minnesota

Prepared under UCLBL P.O. No. 3168702 for: The Energy Efficient Buildings Program, Energy and Environment Division, Lawrence Berkeley Laboratory. Principal Investigators: Craig Hollowell and Art Rosenfeld.

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NOTICE

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Three undergraduate students, George Michaelsen II, Charles Peterson and Steve Preston deserve recognition for their assistance in developing the bibliography on which this report is based. In addition, Mr. Michaelsen and Mr. Peterson gathered data concerning chemical usage in the University of Minnesota Hospitals, while Mr. Preston reviewed literature regarding the history of ventilation usage in hospitals. Mr. M.A. Chatigny of the Naval Biosciences Laboratory and Dr. C.D. Hollowell, Principal Investigator, Lawrence Berkeley Laboratory, are to be thanked for a continuing dialogue and the direction they have provided us.

Finally and perhaps most importantly, Ms. Jean E. Casey handled all of the typing load. She is also due special thanks for her capable handling of the myriad details involved with the production of a report of this magnitude.

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EXECUTIVE SUMMARY

Much attention has been drawn to fuel saving measures for private dwellings and non-priority commercial and public buildings both in the United States and abroad. Health care facilities have been designated thus far as priority users of natural gas, heating oil, and other fuels. However, 76% of American hospitals burn natural gas under their boilers, a practice that may receive increasingly critical scrutiny by local jurisdictions with responsibility for allocating this scarce fuel. There has been a tendency in the United States to set standards of good design and operation--including those for hospital heating, ventilating and air conditioning (HVAC) systems--that provide a very high quality environment for patients and staff. This has been done largely with little or no regard for the energy consumed to provide such an environment. Consequently, hospital building space is considerably more energy intensive than its commercial or public counterpart.

Thus far hospitals have not only been virtually guaranteed an uninterrupted supply of fuel, but there has been considerable reluctance to lower HVAC standards because of concern over possible adverse impact on the health, safety and comfort of patients. Hospital HVAC systems are designed to maximize the well-being of patients and staff, not to minimize the consumption of energy. As the Health Resources Administration observes:

> *There is a limit to how low we can set the thermostat for sick and elderly patients. Air conditioning is*

not a luxury in patient care and certainly not in the operating room. Ventilation made possible by power-driven fans is tightly controlled by Federal regulation. Few appreciate the fact that a hospital is divided into positive and negative pressure zones to reduce the possibility of cross-contamination. Humidity levels are controlled for optimum patient care and to avoid fire and shock hazards in cirtical areas.

The complexity of events in recent years, starting with OPEC's 1973 embargo on petroleum exports to the United States, was directly responsible for Project Independence, a broad, multidimensional federal program designed to achieve energy self-sufficiency in the 1980s. Existing buildings are responsible for an estimated 35% of the nation's energy budget; consequently, building conservation measures were one of Project Independence's priority objectives. This growing energy conservation consciousness has focused attention on the energy performance of buildings and changes in the codes used to guide construction of new buildings. It has been estimated that hospitals consume approximately 15% of all energy used in commercial buildings (the equivalent of 400,000 barrels of oil a day). Approximately 30 to 50% of this energy is used for heating and another 10 to 15% for cooling. Therefore, measures that reduce energy consumption in health care facilities could have a significant impact upon the nation's overall energy consumption.

This University of Minnesota School of Public Health project is based on the premise that current hospital ventilation standards are excessively conservative and impede possible opportunities for HVAC energy conservation strategies. Stated otherwise, relaxation of these standards might provide a further quantum increase

in energy conservation over that possible from hospital energy management programs alone. The objective of this research, therefore, is to examine the basis of current hospital HVAC standards and to determine if they can be relaxed based on criteria that do not compromise the health, safety and comfort of patients and staff and has acceptance of the health care community.

Information has been obtained from the literature and from a small working conference sponsored by the project. The conference was advisory to the University with an objective of obtaining current (i.e., as yet unpublished) thinking with respect to opportunities for and constraints on the relaxation of these standards in the United States to facilitate energy conservation measures. Four Scandinavians were joined by six experts from the United States to form an advisory panel. In addition, 15 observers were invited and made significant contributions to the Panel's deliberations. As extracted from the conference proceedings major recommendations of the panel follow:

1. *The hospital in general is over ventilated and some reduction appears possible. However, in planning for 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 odors needs further research. In particular, Yaglou's work of 1936-37 needs updating in the context of today's technology and cultural factors.*

These recommendations were incorporated into the project's recommendations and guided the direction of the literature review.

Chapter 2 summarizes existing standards in use throughout the United States governing hospital ventilation systems and the thermal environment. Data was gathered by letter contact with each of the states and territories. The letter requested information about hospital ventilation and related standards adopted by the respective governmental unit. Responses have been received from all 50 states and one territory.

Most states adhere to the 1974 Hill-Burton Standard, entitled "Minimum Requirements of Construction and Equipment for Hospital and Medical Facilities." Federal hospital construction standards have been mandated since 1946 with passage of the Hill-Burton Act which 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.

Hill-Burton Program standards are particularly important in that they are specifically oriented toward hospital and other health care facility design and construction. Further, they are widely accepted

within the health care community as specifying minimum acceptable practic. Overall, one conclusion is that present hospital standards as exemplified by those of the Hill-Burton Program, are extremely conservative and difficult to justify on a basis of available knowledge, and may constrain opportunities for energy conservation. At the same time however, there does not appear to be an adequate research base for development of criteria on which an overall revision of these standards could be based.

Chapter 3 explores the role of air in hospital-acquired infections. In the past the literature has contained many reports about the importance of airborne spread of infection. It is thought that one of the reasons for establishing high ventilation rates in the hospital has been to curb the supposed spread of infection by air by reducing the number of airborne particles through dilution with clean air. The control of hospital-acquired infections is a multi-factoral problem because microorganisms, pathogenic and non-pathogenic are ubiquitous. There are numerous sources of potential pathogens in the hospital and the transfer of organisms within a hospital environment is a very complex process. It is technically difficult to document the movement of microorganisms from one area to another and the means by which the transfer occurred be it direct or indirect contact or by the airborne route. Available evidence shows that the airborne route of transfer plays a minor role in infection. More importantly, the literature stresses the need for strict adherence to proper and aseptic technique by all personnel.

Ventilation may affect transfer of microorganisms and the level of contamination, but whether or not it affects infection rates depends on the relative importance of the airborne route to transfer to other routes in a given situation. Indications at the present time are that endogenous flora are responsible for the greatest percentage of nosocomial infections. Exogenous flora transferred by the airborne route assumes a relative minor role in infection and ventilation rates based on the premise of reducing infection are erroneous.

Chapter 4 explores the realm of indoor air quality within the hospital. In some cases there is a definite relationship between outdoor air pollutants and the level of indoor contaminants. Sources within the hospital can also contribute substantially to the chemical contaminant load of the hospital air environment, exposing staff and possibly patients as well to potentially significant hazards.

When considering possible chemical contamination of hospital air, distinction must be made between the effect of indoor air quality on patients and on hospital employees. Protection of the health of each population makes specific demands on the hospital ventilation system.

Perhaps the most important consideration for patient 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.

A second factor to consider in determining the effects of indoor air quality on patients is that their health may be imparied 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. This could be a particular problem in the case of infants, the elderly or people hospitalized with cardiopulmonary or eye problems. Literature dealing with the chemical contaminant loading in the hospital is scarce for patient exposure,but is fairly well documented for some employees such as the operating room team and their exposure to waste anesthetics.

Because of the need for such material the project staff initiated a survey of the University of Minnesota Hospitals to evaluate the chemical load of that particular hospital. Representatives from each operational unit were contacted and asked to provide information on their chemical usage history. Unit representatives were not asked to segregate toxic from nontoxic substances in their inventory, as this might have led to differences in definition of "toxic" from department to department. Results were mixed from this very rudimentary survey. First, it is encouraging to note that no extremely hazardous situation was discovered. Employees, especially those working with highly hazardous chemicals, appear to be following fairly good work practices. Perhaps less encouraging, however, is the realization that such basic inventories are not conducted on a regular basis. The University of Minnesota Hospitals is a teaching/ research institution and has been constructed in stages. This means

that laboratories are often tucked into corners near patient areas and that ventilation in some spots may be less than optimal. Because of the inability of administrators to control these physical characteristics, it would seem that potential problems could be prevented if an effort were made to become aware of chemicals usage patterns.

Chapter 5 contains a discussion concerning the influence of thermal factors on patient comfort. When evaluating the indoor environment with respect to human health and comfort four principal thermal factors must be considered: air (dry bulb) temperature; water vapor pressure, usually expressed as relative humidity (RH); air movement, expressed in terms of velocity and direction; and mean radiant temperature. These are independent variables which must be individually controlled by the researcher when investigating human sensory, physiological and pathological responses to the thermal environment.

Current United States hospital ventilation standards specify the thermal environment primarily in terms of dry bulb temperature (^{o}F and/or ^{o}C) and relative humidity. In contrast to other types of building space, these standards generally specify tighter temperature and humidity requirements ostensibly in order to maintain a stable, supportive patient environment.

Since close control of temperature and humidity consumes large amounts of energy, this chapter considers patient requirements for temperature and humidity control beyond questions of comfort. In this context, temperature and humidity are considered with respect to their physiological, pathological and microbiological implications. Most of the published research is concerned with the thermal comfort of sedentary health subjects, not with seriously compromised patients.

However, an overview of thermal comfort is provided to provide a baseline for further discussion of temperature and humidity.

Temperature restrictions called for by Hill-Burton require a specific temperature ($75^{o}F$) instead of allowing a range, necessitating the use of increased energy. The available literature suggests that there is a much wider comfort zone that would allow for higher indoor summer temperatures and lower indoor winter temperatures.

Hill-Burton humidity requirements are very restrictive and allow for a range of 30-60% relative humidity (RH). The original justification for stringent humidity requirements is thought to be based on some work that suggested that die off of microorganisms was accelerated at 50% RH. Each microorganism reacts differently and only within narrow humidity limits, limits which are more restricted than the Hill-Burton Standard. Consequently, if the standard's tight humidity range is to be justified on the basis of airborne pathogen destruction, a choice must be made as to a specific microorganism or virus. Recent study reports have also shown that humidity does not affect cilia movement, another supposed influence of humidity.

In determining future standards, however, it must be borne in mind that even if mucous and cilia activity, respiratory function and microbial decay do not constrain humidity, other factors such as sensitive electronic equipment and condensation problems may.

Chapter 6 discusses the hospital odor problem with regards to ventilation rates. Odors are a recurring problem within today's complex hospital environment and do cause patient, staff and visitor discomfort.

The primary sources of odors include the patient as well as the multitude of cleaning agents, disinfectants, deodorants and deodorizers which are sometimes used indiscriminantly throughout the hospital. Deodorants and deodorizers simply mask the odorant or induce anosmia and do not remove the odor causing particles.

Ventilation per se should not be used for control of odorants since odors vary logarithmically with concentration, and ventilation rates in excess of 20 air changes per hour may be necessary to reduce a strong odor to an acceptable level. Elimination of sources of odors as well as point source control should be the major strategy used for odor control.

Chapter 7 includes conclusions and recommendations developed from the literature review as well as from the conference. The principles summarized in the chapter are generally applicable to all hospital spaces. They cannot be unilaterally applied, however, without consideration of the unique characterstics of particular spaces such as operating rooms, intensive care units, and isolation rooms. These principles are summarized herein:

1. All hospital spaces other than those used directly for patient care or where unusual health and safety hazards exist, should comply with appropriate ASHRAE energy conservation standards for new or existing commercial buildings.
2. Airborne microorganisms play a minor role in the incidence of nosocomial infections. Therefore, means of minimizing the numbers of airborne biological agents other than by use of outdoor air

can be emphasized, and hospital ventilation standards do not need to be based on control of these agents.

3. Since odor perception versus concentration is a logarithmic function, the outdoor air required to reduce acute odors in the hospital to an acceptable level can be very high. By the same reasoning, low level prevailing odors which are satisfactorily controlled with present ventilation systems are not likely to become problems with a moderate reduction in outdoor air quantities.

4. Generally hospitals are using a wide variety of products for cleaning and disinfection purposes and are frequently not aware of their chemical composition. Many of these products have odors and potentially toxic properties associated with them. This situation dictates that considerable care be taken in assessing implications of reducing outdoor air requirements. However, it is quite likely that the quantities and varieties of these cleaning materials can be reduced, allowing reduction of dilution (outdoor) air requirements.

5. It is quite clear that with respect to patient, staff and visitor comfort, humidity is a minor factor when the temperature is in the comfort envelope. More and more, however, very sensitive electronic patient diagnostic and monitoring equipment is being used in hospitals. In general, such equipment is very sensitive to both high and low moisture

levels. It is therefore anticipated that humidity standards will probably have to be based on the requirements for the proper operation of electronic equipment and the need to prevent moisture damage to hospital equipment and sttructures.

6. Both the Hill-Burton Program standards, and the ASHRAE Handbook specify 75°F dry-bulb temperature for large parts of the hospital. There is no known technical justification for this requirement, other than, perhaps it lies at the middle of the comfort envelope. Adoption of the first principle will relax this requirement for "hospital spaces other than those used directly for patient care or where unusual health and safety hazards exist."

Chapter 7 also includes recommendations for necessary supporting research.

Chapter 1

INTRODUCTION

The worldwide pre-eminence of the United States is largely the result of an energy-intensive industrial economy. The nation is generally blessed with extensive energy resources, although shortfalls in petroleum and natural gas production have occurred as early as the 1950s.

The complexity of events in recent years, starting with OPEC's 1973 embargo on petroleum exports to the United States, is directly responsible for Project Independence, a broad, multidimensional federal program designed to achieve energy self-sufficiency in the 1980s. Existing buildings are responsible for an estimated 35% of the nation's energy budget; consequently, building conservation measures are one of Project Independence's priority objectives.[7]

Much attention has been drawn to fuel saving measures for private dwellings and non-priority commercial and public buildings both in the United States and abroad. Health care facilities have been designated as priority users of natural gas, heating oil, and other fuels. However, 76% of American hospitals burn natural gas under their boilers, a practice that may receive increasingly critical scrutiny by local jurisdictions with responsibility for allocating this scarce fuel.[4]

In 1976, there were 3,776,000 admissions to the 1,434,000 hospital beds in the 7,082 hospitals across the United States.[1] This does not include nursing homes and other long-term health care facilities, which also consume a significant portion of this nation's energy supply 24 hours per day, 7 days per week. It has been estimated that hospitals consume approximately 15% of all energy used in commercial buildings (the equivalent of 400,000 barrels of oil a day). Approximately 30 to 50% of this energy is used for heating and another 10 to 15% for cooling. Therefore, measures that reduce energy consumption in health care facilities could have a significant impact upon the nation's overall energy consumption.

It is generally agreed that the quality of the environment in health care facilities such as hospitals and nursing homes must be better than that provided for the general public in eating and lodging facilities and places of assembly. This is based on the premise that patients are already under stress and that they should not be subject to additional stress resulting from environmental shortcomings. An additional consideration is that patients are exposed to the health care environment 24 hours per day, with limited or no opportunity to escape from that setting. It is also thought that the quality of the hospital environment should be and can be actually supportive of the patient rather than stressful.

As a result of these arguments, there has been a tendency in the United States to set standards of good design and operation--including those for hospital heating, ventilating and air conditioning (HVAC) systems--that provide a very high quality environment for patients and staff. This has been done largely with little or no regard for the

energy consumed to provide such an environment. Consequently, hospital building space is considerably more energy intensive than its commercial or public counterpart.

Thus far hospitals have not only been virtually guaranteed an uninterrupted supply of fuel, but there has been considerable reluctance to lower HVAC standards because of concern over possible adverse impact on the health, safety and comfort of patients. Hospital HVAC systems are designed to maximize the well-being of patients and staff, not to minimize the consumption of energy. As the Health Resources Administration observes:

> *There is a limit to how low we can set the thermostat for sick and elderly patients. Air conditioning is not a luxury in patient care and certainly not in the operating room. Ventilation made possible by power-driven fans is tightly controlled by Federal regulation. Few appreciate the fact that a hospital is divided into positive and negative pressure zones to reduce the possibility of cross-contamination. Humidity levels are controlled for optimum patient care and to avoid fire and shock hazards in critical areas.*[3]

Emphasis on hospital ventilation has a long history, beginning in the first century A.D. with a Roman military hospital in which each room had a window for ventilation. Over the next several centuries, "hospitals" consisted of large open halls, heated and ventilated by four fireplaces such as the monastery of Clumy, France (1043 A.D.). The halls were well ventilated but not very well heated, necessitating curtaining off the patient so that his own body heat would keep him warm. The Ospedale Maggiore of Milan (1456) partially solved this problem by running a line of braziers down the middle of the ward.[6]

In the military hospitals of the day were found the best heating and ventilation. Two examples of hospitals with good ventilation were the Royal Navy Hospital in Plymouth, England (1764-65) and James Tilton's hospital termed the "Indian Hut." In the "Indian Hut," there was a fire in the middle of the ward, without a chimney, allowing the smoke to raise up in the center above the patients' heads. The smoke helped "combat infections" and was not offensive because it was above the patients' heads.[6]

The civilian hospitals of the 17th and 18th centuries were not as well developed as the military hospitals. At the time, it was thought that disease was caused by poisonous gases, miasmas, and pestilential exhalations so that ventilation was the primary goal of hospital architecture. Some hospitals essentially became wind tunnels such as Cesar Laure's crossward plan for the Hotel Dieu of Lyons (1622-31) which had a dome over the chapel at the crossing where foul air was supposed to collect. There was a fireplace burning all the time for ventilation and two large cast-iron stoves for heat. The ventilation was so good that on winter mornings the temperature in the chapel would be as low as 27.5° F. On the other extreme, it was thought that free circulation of air should be prevented and that to protect the patients from disease, the windows should be sealed and heavy curtains placed around the beds as found in the Rotunda Maternity Hospital of Dublin (1757).[6]

The Nightingale ward became prominent in the 19th century. Florence Nightingale was the first female nurse to care for British soldiers, and she made dramatic improvements in mortality rates

by insisting on a scrupulously clean, well-ventilated hosptial. The Nightingale ward was an oblong room with windows on both sides. Sanitary facilities were at one end, partitioned and independently ventilated, while an open fireplace was centrally located for heat and ventilation.[6]

By the middle of the 19th century, air was being introduced into rooms from the outside by tubes through small openings so as not to produce inconvenient drafts. The exhaust air was removed through vents that were larger than the intake vents. This system relied on the principle that a fire in the fireplace can be used to suck the air out of a room through the chimney.

In 1861, an American Sanitary Commission (ASC) report recommended that hospitals should provide ample heating and ventilation and that hospitals should be specially constructed instead of trying to make hospitals out of existing buildings where the heating and ventilation was already a problem.[6]

In the United States the Civil War military hospitals were, as in the past, making important developments with heating and ventilation. As a result of the ASC report, Lincoln Hospital was constructed on the same principle as Tilton's "Indian Hut." The barracks were ventilated by four ventilation gratings at regular distances in the floor of the ward; wood flues carried air from the outside giving the ward fresh air even when the doors and windows had to be closed.[6]

The John Hopkins Hospital of Boston built in 1887 was probably the first hospital built with modern day heating and ventilation. In the building, air was drawn in through the basement which had many

coils of cast-iron pipe on the outer walls which carried water that could be heated to 150° F. The air was drawn into the ward through a vent between the beds. There were two series of outlets to remove air from the wards; one was located under the beds, and the other was in the ceiling. In cold weather, only the lower system was used but both systems were used in hot weather to thoroughly circulate the air.[6]

Formal standards for hospital ventilation did not appear, however, until the late 1950s and early 1960s under the federal Hill-Burton Program that provides financial support for the construction of hospitals. Early in the Hill-Burton Program it became evident that design standards would have to be developed, applicable to all hospital construction funded by the federal government. Over the years, these standards have become accepted as the minimum requirement for hospital design even in situations where federal funds are not involved. It is likely that many of these standards are overly conservative and thus energy inefficient in the light of new information developed over the past decade or so.

Research has demonstrated conclusively that older buildings require far more energy than is necessary to achieve the objectives for which they were designed and built. Hospitals are, of course, no exception. More than 90% of the nation's hospitals were built or designed prior to 1973-74 and are thus energy inefficient by today's standards.[7] Therefore, the first major thrust for hospital energy conservation is that of implementing various engineering measures to reduce energy consumption (i.e., energy management). These

engineering changes in design and operation do not in themselves alter the quality of the environment, but provide the same quality with greater energy efficiency. Possibilities include:

1. Employ low pressure air distribution systems;
2. Decrease boiler pressure;
3. Employ hot water heating;
4. Discontinue reheat system for individual room temperature control; and
5. Provide centralized facilities for operations which are energy intensive and not directly related to patient care, including computer facilities, kitchens, laundry, and possibly central sterile supply.

It must be noted that all of these measures can be undertaken without affecting the quantity of ventilation air used; i.e., the hospital would remain in conformance with current ventilation standards.

The discussion above, however, suggests that the current standards may well be overly conservative and therefore excessively energy intensive. Thus, a second strategy for energy conservation is through a systematic reassessment of hospital ventilation standards.

Relaxation of these standards would allow consideration of additional schemes which 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. Possibilities include:

1. Reduce overall ventilation rates;
2. Reduce outside air requirements;
3. Use lower efficiency air cleaning equipment;
4. Increase the use of recirculated air;

5. Reduce building temperatures in winter and increase temperatures in summer;

6. Relax humidification requirements;

7. Employ air-to-air energy recovery systems; and

8. Shut down ventilation systems when not needed.

These strategies could affect the indoor air environment in four general areas:

1. Biological agents, regarding hospital-acquired infections and air hygiene.

2. Low-level chemical contaminants from sources within the hospital, including toxic anesthetic gases, as well as outside air pollutants, both gaseous and particulate.

3. Thermal properties, i.e., dry bulb temperature, wet bulb temperature, mean radiant temperature and air velocity.

4. 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.

Consequently, it is necessary to assess the extent to which each constrains ventilation air requirements. The results of such an inquiry are documented in this report, with an objective of forming a technical basis for recommendations as to:

1. Possible relaxation of current hospital ventilation standards, based on criteria that do not compromise the health, safety and comfort of patients and staff and have the acceptance of the health care community;and

2. Necessary research to fill information gaps.

Information contained herein was developed from two primary sources: a literature review, and a small working conference sponsored by the project.

The literature review examined relevant foreign and domestic original documents, both published and unpublished, with emphasis on the literature appearing since 1965. The reason for this is that the majority of hospital ventilation standards was established prior to 1965, and it is likely that many are overly conservative--and thus energy inefficient--in light of new information developed over the past decade. Numerous references in the engineering, medical, hospital administration, microbiology, physiology, and toxicology disciplines were examined in development of a comprehensive literature summary. This material is documented hereinafter. Chapter 2 summarizes existing federal and state hospital HVAC standards, while Chapters 2 through 6 examine the indoor air environment with respect to each of the four factors cited above. The objective of each chapter is to assess the extent to which the respective factor constrains ventilation requirements in the hospital context.

The other primary source of information was provided through sponsorship of an International Working Conference on Hospital Ventilation Standards and Energy Conservation, held in the Gemini Room, IDS Center, Minneapolis on February 21-23, 1978. The Conference was advisory to the University with an objective of obtaining current (i.e., as yet unpublished) thinking with respect to opportunities for and constraints on the relaxation of these standards in the United States to facilitate energy conservation measures. The Conference invitation addressed this in further detail:

Precise knowledge of alternatives to present standards and practices in the design and operation of hospital ventilation systems from the standpoint of patient welfare and energy conservation is, for a large part, nonexistent. Therefore, it is necessary to rely on knowledgeable persons in such areas as man's physiological needs, special problems of the hospital environment, energy conservation, control of airborne contaminants and engineering practice.

Northern European countries are very progressive in hospital design and HVAC systems as related to patient care and energy conservation. These countries have already had several years of experience in dealing with high energy costs without sacrificing quality of health care delivery. The International Working Conference will draw upon the experiences and expertise of four experts from these countries by meeting with representatives from the United States to consider alternatives and to advise the University of Minnesota on problems of patient care and comfort while giving serious consideration to energy conservation...

The major task of the panel will be to review present standards for the design and operation of HVAC systems from the biological, chemical, physical and aesthetic standpoint to see if these standards and practices can be relaxed without compromising the health and well being of patients and staff....The Conference is advisory to the project with a twofold objective:

--To determine what is already known that could lead to developing changes in hospital ventilation standards to conserve energy, and

--To determine what information gaps exist that could lead to further energy conservation through additional changes in ventilation standards.

The four Scandinavians were joined by six experts from the United States to form an Advisory Panel. In addition, 15 observers were invited and made significant contributions to the Panel's deliberations.

The agenda was organized around discussion of the four aforementioned factors for the first two days. The third day was devoted to developing the panelists' recommendations to the project . Major points include:

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 odors needs further research. In particular, Yaglou's work of 1936-37 needs updating in the context of today's technology and cultural factors.*[5]

The Conference Proceedings are documented elsewhere.[5] However, Appendix A contains a list of the Advisory Panel members, and the full text of their position statements and recommendations.

The literature research and Conference are merged herein in Chapter 7 which provides conclusions and recommendations. Therein, a set of principles is articulated on which revised hospital ventilation standards could be based, as well as a series of relevant research recommendations.

References

1. American hospital association guide to the health care field. Chicago: American Hospital Association, 1977.

2. ANDERSON, J.L., R.S. BANKS and G.S. MICHAELSEN. Hospital ventilation standards and energy conservation: a preliminary assessment of the Literature. University of Minnesota, School of Public Health, February 1978.

3. Energy strategies for health care institutions. U.S. Department of Health, Education,and Welfare, Public Health Service, Health Resources Administration, 1976.

4. Energy survey results provide information on hospital fuel sources. Hospital Engineering, 22(6): 1, 4-5, November/December 1977.

5. Hospital Ventilation Standards and Energy Conservation: Proceedings of the 1978 International Working Conference. George S. Michaelsen, Conference Chairman, Minneapolis: University of Minnesota School of Public Health, August 1978.

6. THOMPSON, J.D. and G. GOLDIN. The hospital: a social and architectural history. Forge Village, Massachusetts: The Murray Printing Compnay, 1975.

7. Total energy management for hospitals. U.S. Department of Health, Education, and Welfare, Public Health Service, Health Resources Administration. DHEW Publication No. (HRA) 77-613.

Chapter 2

HOSPITAL VENTILATION AND THERMAL STANDARDS

There is increasing awareness that development of more efficient and reliable energy resources is not a short-term but a long-term solution to the energy crisis, resulting in a greater national emphasis on energy conservation programs. This growing energy conservation consciousness has focused attention on the energy performance of buildings and changes in the codes used to guide construction of new buildings. This chapter summarizes existing standards in use throughout the United States, governing hospital ventilation systems and the thermal environment. It is intended to provide a baseline for assessing opportunities for and constraints on energy conservation measures.

MODEL CODE FOR ENERGY CONSERVATION IN NEW BUILDING CONSTRUCTION

With passage of the Energy Policy and Conservation Act of 1975 (PL 94-163), the United States Congress mandated establishment of federal guidelines requiring that certain levels of energy-efficiency be achieved in new building construction. Virtually all states have responded to these guidelines and are now participating in this program. Under this program, a state may voluntarily enter into a cooperative effort with the federal government to further that state's energy conservation efforts. Each state bears the responsibility for developing and implementing a comprehensive state energy conservation plan. The federal government, in turn, provides both technical assistance

and financial support. To assist these states and local building code officials in the development, adoption and implementation of energy conservation codes for new buildings, the United States Department of Energy (DOE) funded the development of a model building design code establishing minimum energy conservation levels in new building construction. The model code,"Code for Energy Conservation in New Building Construction", is the result of a contract between the National Conference of States on Building Codes and Standards, Inc. (NCSBCS)and DOE. [3] The DOE funding support provided that NCSBCS contract with the three model code groups, Building Officials & Code Administrators International, Inc.; International Conference of Building Officials; and Southern Building Code Congress International,Inc., to work together in a joint effort to produce this document. The Code incorporates ongoing energy conservation code development efforts by the three model code groups as well as various state energy conservation activities.

Extracting from the Code itself, its intent and scope are as follows:

101.2 Intent

> *The provisions of this Code shall regulate the design of building envelopes for adequate thermal resistance and low air leakage and the design and selection of mechanical, electrical, and illumination systems and equipment which will enable the effective use of energy in new building construction. . . This Code is not intended to abridge any safety or health requirements required under any other applicable codes or ordinances.*

101.3 Scope

> *This Code sets forth minimum requirements for the design of new buildings and structures or portions thereof and additions to existing buildings that provide facilities or shelter for public assembly, education, business, mercantile, institutional,*

storage and residential occupancies, as well as those portions of factory and industrial occupancies designed primarily for human occupancy by regulating their exterior envelopes and the selection of their HVAC, service water heating, electrical distribution and illuminating systems and equipment for effective use of energy. [3] *(emphasis added)*

In effect, implementation of the Code means that, in the interest of energy conservation, new buildings which are used primarily for human occupancy(including residences, office space, portions of factory and industrial occupancies, educational facilities, or shelter for public assembly, business,etc.) must meet minimum design requirements ensuring efficient use of energy.

Functionally, the Code was developed to serve three major purposes:

1. Provide, in language compatible with current building codes, energy conservation standards for new building construction that are based upon technical criteria developed by the American Society of Heating, Refrigerating and Air Conditioning Engineers,Inc. (ASHRAE), embodied in ASHRAE Standard 90-75, "Energy Conservation in New Building Design." Each paragraph of this standard was reviewed for appropriateness as an enforceable provision with applicable sections modified into code language. These sections are considered no less stringent than ASHRAE Standard 90-75. The Code has also been restructured in relation to the ASHRAE standard, and requirements to regulate new additions to existing buildings and acceptable practice provisions have been added.
2. Take into account codes reflecting a concern for energy conservation that have already been developed by various states and model code groups. This was done to ensure that the Code is compatible

and, therefore, acceptable to all the concerned state and local code groups. Moreover, the Code takes a comprehensive approach, as opposed to other codes, which do not consider all elements of the ASHRAE standard and all building types.

3. Include administrative provisions to facilitate adoption and implementation of the Code by states and local governmental units.

Interest in this report is with the thermal environment and ventilation. The Code specifies the following:

302.2 Interior Design Conditions

(a) Indoor Design Temperature. Indoor design temperature shall be 72 F for heating and 78 F for cooling.

EXCEPTION: Other design temperatures may be used for equipment selection if it results in a lower energy usage.

(b) Humidification. If humidification is provided during heating, it shall be designed for a maximum relative humidity of 30 percent. When comfort air conditioning is provided, the actual design relative humidity within the comfort envelope as defined in Std RS-4 shall be selected for minimum total HVAC system energy use.

303.1 Ventilation

Ventilation air shall conform to Std RS-3. The minimum column value of Std RS-3 for each type of occupancy shall be used for design. The ventilation quantities specified in Section 6 of Std RS-3 are for 100 percent outdoor air ventilating systems. Reduction of up to 33 percent of the specified minimum outdoor air requirement in Section 5 of Std RS-3 for recirculation HVAC systems is permitted.

EXCEPTIONS: If outdoor air quantities other than those specified in Std RS-3 are used or required because of special occupancy or process requirements, source control of air contamination, health and safety or other standards, the required outdoor air quantities shall be used as the basis for calculating the heating and cooling design loads. [3] *(emphasis added)*

"Std RS-3" and "Std RS-4" refer to, respectively:

1. ASHRAE Standard 62-73, "Natural and Mechanical Ventilation" (ANSI B 194.1-1977) (see below); and

2. ASHRAE Standard 55-74, "Thermal Environmental Conditions for Human Occupancy" (ANSI B 193.1-76).

These standards are incorporated by reference within the Code.

HOSPITAL VENTILATION AND THERMAL STANDARDS

The Code will form the backbone of state-level building energy conservation programs throughout the United States. Nonetheless, it must be placed in perspective with respect to hospitals and other health care institutions. The Code specifically states that it is "not intended to abridge any safety or health requirements required under any other applicable codes or ordinances." [3] This one statement, in effect, exempts hospital ventilation and thermal requirements from the energy conservation consciousness reflected in development and adoption of this new code for building construction.

Instead, hospital construction is guided by design and construction standards which are oriented strictly toward patient care and possibly erring on the side of safety. As a result, contemporary hospitals are relatively and perhaps needlessly, energy intensive compared to commercial and public building space.

The purpose of this report is, of course, to assess hospital ventilation (and thermal) standards with respect to their potential for relaxation as an energy conservation measure. As part of this effort, hospital ventilation and thermal standards in use in the United States have been collected and summarized, as presented in this chapter.

Methodology

Letter contact was made with the individual responsible for health care facility licensure in each of the states and territories. This individual was identified from information compiled by the Association of State and Territorial Health Officers. These recipients were sent a form letter requesting information on hospital ventilation and related standards adopted by the respective state. In general, replies consisted of a transmittal letter providing explanatory comments and a copy of the state's rules for health facility design and construction. Responses have been received from all 50 states and one territory. In a similar fashion, the five federal agencies known to construct and operate hospitals were contacted.

A draft of this chapter was mailed to all respondents, asking for critical review and comment. Some responses were received and have been incorporated herein.

Many states use a national standard, either formally adopted or informally applied. These standards are summarized herein in Tables 2.1 to 2.5. Other govermental units have developed unique standards, as tabulated in Table 2.6.

Individual standards, both national and governmental unit, are presented in a common matrix format as shown in Figure 2.1 to facilitate comparision. All standards are presented in this form except ASHRAE Standard 62-73 (Table 2.3) and that adopted by the Department of the Air Force (Table 2.6.1). These two standards specify ventilation air requirements on a CFM basis rather than air changers per hour; consequently

their column headings have been altered. Row headings (i.e., area designations) are consistent throughout.

Conventions adopted in preparation of Tables 2.1 through 2.6 are:

N = Negative pressure to be maintained with respect to surrounding spaces.

P = Positive pressure to be maintained with respect to surrounding spaces.

E = Equal pressure to be maintained with respect to surrounding spaces.

V = Pressure may vary with respect to surrounding spaces.

- = No data specified.

CFM = Cubic feet per minute.

Requirements specified in these tables are minimums and are not intended to prelude higher ventilation rates for heating or cooling.

In addition to tabular information, each table includes supplemental requirements and explanatory notes.

National Standards

Many states utilize national standards, which have been adopted by reference, explicitly codified as a state rule, or simply informally adopted as prima facie evidence of accepted design and construction practice.

There are presently three sources of national standards concerned with hospital ventilation air and thermal requirements:

1. U. S. Department of Health, Education and Welfare, Public Health Service, Health Resources Administration: minimum design and construction requirements under the Hill-Burton program.

2. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.: applicable engineering standards.

3. National Fire Protection Association: Life Safety Code.

Each of these is discussed below.

Hill-Burton Standard (Tables 2.1 and 2.2). Federal hospital construction standards have been mandated since 1946 with passage of the Hill-Burton Act which 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 original "General Standards" appeared in the Federal Register on February 14, 1947, as part of the original regulations relating to the implementation of the Hill-Burton Program. Since that time, the standard has been revised several times to maintain relevancy to the functional and technological advances in health care and in construction practice as they affect the delivery of health care. Hospital architects, administrators and medical advisors have comprised the technical committees which drafted these revisions.[8]

These standards have evolved over the years, generally toward increased ventilation air requirements and higher temperature and humidity control.[5,6] Infection control is the basis of these standards; the air change rates is intended to maintain viable particle counts per cubic foot below specified levels for different hospital areas. These levels were based on surveillance studies conducted by the Communicable Disease Center in the early 1960s. From these studies Galson and Goddard concluded "that definite standards for hospital environments are economically feasible and could be established."[5] As discussed in Chapter 3, however, the role of air in hospital-acquired infections has been over emphasized and thus the conclusions of the CDC studies are challengeable, in light of more current studies.

Although there is a 1976 Hill-Burton Standard, the 1974 version is the more generally recognized. The differences between the two are apparently primarily editorial. The 1974 Hill-Burton Standard, entitled "Minimum Requirements of Construction and Equipment for Hospital and Medical Facilities," is a revision of "General Standards of Construction and Equipment for Hospital and Medical Facilities" issued in 1969 and has been reduced in scope to specify only minimum requirements.[8]

For more than two years, technical study groups, under Hill-Burton auspices, regularly met to draft this document. These groups evaluated comments by various federal and state agencies as well as medical, construction, and design authorities. Consideration was also give to comments received as a result of a notice which appeared in the Federal Register on June 28, 1973.

The standard specifies minimum requirements that "are considered necessary to ensure properly planned and well constructed health care facilities which can be efficiently maintained and operated to furnish adequate services."[8] It does not infringe upon an individual state's right to impose more stringent requirements, stating:

> *Because of local conditions, states may have additional requirements, some of which may exceed those detailed herein. Neither these minimum requirements nor the guide materials mentioned above are intended in any way to restrict innovations and improvements in design or construction techniques. Accordingly, plans and specifications which contain deviations from the requirements perscribed herein may be approved if it is determined that the purposes of the minimum requirements have been fulfilled. Requests to waive any specific requirement shall be submitted to DHEW's Division of Facilities Utilization, Health Resources Administration, as early in the planning process as possible.*[8]

In addition, it specifies its relationship to other codes and standards as follows:

> *Nothing stated herein shall relieve the sponsor from compliance with building codes, ordinances, and regulations which are enforced by city, county, or state jurisdictions. Where such codes, ordinances, and regulations are not in effect, the sponsor shall consult one of the national building codes generally used in the area for all components of the building type which are not specifically covered by these minimum requirements, provided that the requirements of the national code are consistent with the minimum requirements set for therein.* [8]

A draft of a new ("Proposed") Hill-Burton Standard (Table 2.1) appeared in February 1978. As of this writing, however, a new standard has not been officially promulgated.

With respect to ventilation and thermal requirements, some differences between the 1974 and Proposed Standards are evident. Temperature requirements will be relaxed in some areas, although humidity requirements will now be specified for all areas. Some areas will now be able to have a variable pressure relationship with adjacent areas, which may provide some energy savings. Perhaps of most interest will be an optional requirement for operating rooms, allowing either 15 changes per hour of outside air or 5 changes per hour of outside air with 25 total air changes per hour. It is not clear that any of these new requirements resulted from energy conservation considerations.

Hill-Burton Program standards are particularly important in that they are specifically oriented toward hospital and other health care facility design and construction. Further, they are widely accepted within the health care community as specifying minimum acceptable practice. Nonetheless, it must also be recognized that these standards may be excessively conservative, possibly constraining opportunities for major energy conservation measures.

ASHRAE Standards (Tables 2.3 and 2.4) The American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE) provides two sources of hospital ventilation standards recognized by some states:

1. Formal engineering standards; and
2. Guidelines contained in the ASHRAE Handbook and Product Directory.

The relationship between these sources is not entirely clear; consequently, each will be discussed separately.

ASHRAE engineering standards are established to assist the HVAC industry and the public by offering a uniform method of testing equipment for rating purposes, by suggesting safe practices in designing and installing such equipment, by providing proper definitions of this equipment, and by providing other information which may serve to guide the industry. The creation of these standards is determined by need, and conformance is completely voluntary. Adherance is perceived as solely in the interest of obtaining uniform standards throughout the industry, vis-a-vis other interests such as public health and safety. Equipment ratings published as conforming to an ASHRAE standard must comply with the publication provisions stated therein.[10]

ASHRAE standards are updated on a five-year cycle. Each title is preceded by a number; the digits before the hyphen refer to the standard designation,and the digits after the hyphen refer to the year of approval, revision or update. Appearance of an "ANSI" designation reflects approval by the American National Standards Institute.

ASHRAE standard 62-73, "Standards for Natural and Mechanical Ventilation" (ANSI B 194.1-1977) establishes:

> *. . . ventilation requirements for spaces intended for human occupancy and specifies minimum and recommended ventilation air quantities for the preservation of the occupants' health, safety, and well-being.*

Good ventilation practices exists when clean ventilation air is provided in sufficient quantities to maintain the required oxygen, carbon dioxide, and other air quality levels, in the space under consideration.

The standard does not specify the air quantities required for the control of temperature and humidity or the exhaust quantities required for source control of domestic or industrial wastes. The specifications are based on the current state of knowledge and acceptable practice related to air filtration, odor control and environmental physiology.[10] *(emphasis added)*

The standard specifies ventilation air (i.e., "that portion of supply air which comes from outside . . . plus any recirculated air that has been treated to maintain the desired quality of air within a designated space.") requirements for a variety of building spaces, including residential, commercial, industrial, agricultural, institutional, and organizational facilities.[10] Requirements for hospitals are tabulated in Table 2.3.

The introduction provides some historical perspective on this standard:

The importance and confusion regarding the need for ventilation standards is evidenced by the existence of such standards in numerous building codes since the early 1900's and, at the same time, the diverse and often conflicting specifications. In 1965, ASHRAE was invited to participate in the revision and updating of ASA Standard A53.1, Light and Ventilation, dated May 23, 1946. Responsibility for the Mechanical Ventilation Section of this Standard was assigned to an ASHRAE Project Committee appointed in 1966. With the reorganizatin of ASA (now ANSI) and a change in its procedures, the A53 Committee became inactive; at the instructions of the ASHRAE Standards Committee, the Project Committee was advised to continue its efforts and develop an ASHRAE Standard.

To meet its responsibility, the Project Committee undertook an extensive program to obtain input from all segments of industry, the public, and ASHRAE members. A comprehensive review and comparison of ventilation codes was undertaken to aid the Committee in its formulation and standardization of definitions and recommendations. An article in the ASHRAE Journal

and a press release to the trade press solicited opinions, comments and suggestions. An open forum was held at the ASHRAE Semi-annual Meeting in Chicago, January 1969. Interest was high and considerable information was obtained for guidance of the Project Committee. Following Project Committee acceptance of the eight draft, the proposed Standard was submitted to an additional review by ASHRAE members and representatives from industry and government prior to approval by the Standards Committee and ASHRAE's Board of Directors.

The Standard recommends ventilation rates based upon the best available scientific and technical knowledge. It also incorporates, for the first time, a quantitative definition of "acceptable outdoor air" and specifies conditions under which the amount of outdoor air may be reduced, thereby taking advantage of advancements in air cleaning technology.[10]

The technical basis of this standard must be understood. It establishes requirements based on the state of knowledge with respect to "air filtration, odor control and environmental physiology," vis-a-vis infection control.[10] Consequently, the minimum ventilation air requirements are specified in terms of "cubic feet per minute, per human occupant," rather than air changes per hour.[10] It is therefore difficult to make an overall comparison of ASHRAE Standard 62-73 with standards oriented strictly to the hospital environment.

One analysis, however, may be illustrative. Section 6.5, "Institutions," of ASHRAE Standard 62-73, specifies that hospital "single, dual bedrooms "shall have a minimum ventilation air rate of 10 CFM per occupant, and provides an estimate of 15 persons per 1000 square feet of floor area.[10] If a ceiling height of nine feet is assumed, this amounts to 1.0 ventilation air changes per hour. In contrast, the proposed Hill-Burton Standard requires two changes of outdoor air per hour, double the ASHRAE standard. Presumably the factor of two is intended to provide for infection control; i.e., air requirements beyond that for odor control and physiological needs.

The standard only specifies ventilation air requirements. A companion document, ASHRAE Standard 55-74, "Thermal Environmental Conditions for Human Occupancy" (ANSI B 193.1-76), provides thermal comfort criteria. This is a performance standard specifying the environmental conditions that will provide year-round thermal acceptability for at least 80% of normally clothed men and women living in the United States and Canada, while engaged in indoor sedentary or near sedentary activities, such as light office work, at altitudes of sea level to 7,000 feet. The specifications are based on the current state of knowledge of environmental physiology, comfort research, and commercial practice. This standard is not applicable to spaces in which the activity level is greater than that of light office work or for other than indoor clothing.[11]

Satisfaction with the thermal environment is a complex subjective response to several interacting variables. This standard has meaning only when the criteria established by it are applied together and in the manner outlined therein. It is necessary that those applying ASHRAE Standard 55-74 realize that the thermal performance of an occupied space is determined by the design and construction of the space as well as the heating, cooling, ventilation and air cleaning systems and their controls.[11]

ASHRAE Standard 55-74, in terms of its scope, is not applicable to the patient environment. Consequently, it cannot be unilaterally applied to the hospital setting, and no thermal comfort criteria from it are included herein.

The other source of ASHRAE standards are guidelines contained in the ASHRAE Handbook and Product Directory. The Handbook contains four volumes, providing a comprehensive and current source of reference data on air conditioning, heating, ventilation and refrigeration. Besides technical data sections, each volume includes a Product Directory,

listing the names and addresses of over 4500 manufacturers and organized under 1000 product categories; a Catalog Data section, illustrating products of leading manufacturers for rapid reference to modern equipment; and an Index of Technical Data.

Each of the four volumes is undated on a staggered four year cycle such that an updated Handbook volume is published annually. The present four volumes are:

1977 Fundamentals (Current until 1981)

1976 Systems (Current until 1980)

1975 Equipment (Current until 1979)

1978 Applications (Current until 1982)

The 1978 Applications volume "presents information on the use of various components, units and systems to provide specific conditions for a building occupancy or as required for a process."[2] It specifies hospital ventilation air requirements as tabulated in Table 2.4. Since the accompanying text discusses such issues as infection control, presumably these requirements are so based. This is also evident from a comparison with the Hill-Burton Standard: The 1978 Applications volume specifies very similar outdoor air requirements.

Although these requirements are recognized by some states, it is important to recognize that they are not formal engineering standards. Updating the Handbook volumes is the responsibility of ASHRAE's various technical committees, and there is no assurance of review by other interest groups as would be the case with a standard adopted by the mechanisms of the American National Standards Institute. Nonetheless the Handbook is an excellent source of state of knowledge reference data for designers, with a higher degree of acceptability for the hospital environment than ASHRAE Standard 62-73.

Life Safety Code (Table 2.5) This Code is prepared under sponsorship of the National Fire Protection Association under the formal designation of NFPA 101, "Code for Safety to Life From Fire in Buildings and Structures." The Code's purposes and scope are:

SECTION 1-2. PURPOSE

1-2111. The purpose of this Code is to specify measures which will provide that degree of public safety from fire which can be reasonably required. The Code endeavors to avoid requirements which might involve unreasonable hardships or unnessary inconvenience or interference with the normal use and occupancy of a building, but insists upon compliance with a minimum standard for fire safety necessary in the public interest, even though a financial hardship may be involved in some individual cases.

SECTION 1-3. SCOPE

1-3111. This Code deals with life safety from fire and like emergencies. It covers construction, protection, and occupancy features to minimize danger to life from fire, smoke, fumes, or panic before buildings are vacated. It specifies the number, size,and arrangement of exit facilities sufficient to permit prompt escape of occupants from buildings or structures in case of fire or other condition dangerous to life.

The Code recognizes that life safety is more than a matter of exits and accordingly deals with various matters besides exits which are considered essential to life safey and, in some cases, specifies limits beyond which the hazard is so great that no practical amount of exits can give assurance of any reasonable safety.[7]

The Life Safety Code has a long and distinguished history, and it is worthwhile to dwell briefly on its origin and development to place it in context with respect to hospital ventilation:

The Life Safety Code had its origin in the work of the Committee on Safety to Life of the National Fire Protection Association which was appointed in 1913. For the first few years of its existence the Committee devoted its attention to a study of the notable fires involving loss of life and in analyzing the causes of this loss of life. This work led to the preparation of standards for the construction of stairways, fire escapes, etc., for fire drills in various occupancies and for the construction and arrangement of exit facilities for factories, schools, ect., which form the basis of the present Code. These reports were adopted by the National Fire Protection Association and published in pamphlet

form as "Outside Stairs for Fires Exits: (1916) and "Safeguarding Factory Workers from Fire" (1918). A pamphlet, "Exit Drills in Factories, Schools, Department Stores and Theatres," published in 1912 following its presentation by the late Committee member, Mr. R. H. Newbern, at the 1911 annual meeting of the Association, although antedating the organization of the committee, is considered as having the status of a Committee publication and had been used with the other pamphlets as a ground work for the present Code. These pamphelts were widely circulated and put into quite general use.

In 1921 the Committee was enlarged to include representation of certain interested groups not previously participating, and work was started on the further development and integration of previous Committee publications to provide a comprehensive guide to exits and related features of life safety from fire in all classes of occupancy, to be known as the Building Exits Code. Various drafts were published, circulated and discussed over a period of years and the first edition of the Building Exits Code was published by the National Fire Protection Association in 1927. Thereafter the Committee continued its deliberations, adding new material on features not originally covered, and revising various details in the light of fire experience and practical experinece in the use of the Code. New editions were published in 1929, 1934, 1936, 1938, 1939, 1942, and 1946 to incorporate the amendments adopted by the National Fire Protection Association.

The Cocoanut Grove Night Club fire in Boston in 1942 in which 492 lives were lost focused national attention upon the importance of adequate exits and related fire safety features. Public attention to exit matters was further stimulated by the series of hotel fires in 1946 (LaSalle, Chicago-61 dead; Canfield, Dubuque-19 dead; and the Winecoff, Atlanta-119 dead). The Building Exits Code thereafter was used to an increasing extent for legal regulatory purposes. However, the Code was not in suitable form for adoption into law, as it had been drafted as a reference document containing many advisory provisions useful to designers of buildings, but not appropriate for legal use. This led to a decision by the committee to re-edit the entire Code limiting the body of the text to requirements suitable for mandatory application and placing advisory and explanatory material in notes. The re-editing also involved adding to the Code provisions on many features in order to produce a complete document. Preliminary work was carried on concurrently with development of the 1948, 1949, 1951, and 1952 editions. The results were incorporated in the 1956 Edition, and further refined in subsequent editions dated 1957, 1958, 1959, 1960, 1961, and 1963.

In 1955, separate documents, NFPA 101B and NFPA 101C were published on nursing homes and interior finish, respectively. NFPA 101C was revised in 1956. These publications have since been withdrawn.

In 1963 the Safety to Life Committee was reconstructed. The Committee was decreased in size to include only those having very broad knowledge in fire matters and representing all interested factions. The Committee serves as a review and correlating committee for seven Sectional Committees whose personnel include members having a special knowledge and interest in various portions of the Code.

Under the revised structure, the Sectional Committees through the Safety to Life Committee prepared the 1966 edition of the Code which was a complete revision of the 1963 edition. The Code title was changed from Building Exits Code to the Code for Life Safety from Fire in Buildings and Structures, the text was put in "code language: and all explanatory notes were placed in an appendix. The contents of the Code were arranged in the same general order as contents of model building codes because the Code is used primarily as a supplement to building codes.

New editions of the Code were adopted in 1967 and 1970, and the Code was placed on a three-year revision schedule.

In all of the work in developing the various sections of the Code the groups particularly concerned have been consulted. Reports have been published by the NFPA for review by all concerned and have been discussed and adopted in the annual meetings of the NFPA. Records of the discussions and action taken by the NFPA will be found in the Technical Committee Reports and the NFPA Fire Journal . . .[7]

The 1970 edition of the Life Safety Code was approved by the American National Standards Institute on July 27, 1971 and designated ANSI A9.1. The 1973 edition superseded the 1970 edition and was adopted by the National Fire Protection Association on May 17, 1973.

While the Code is primarily concerned with the exit facilities, it does extend to numerous other subject areas concerned with public safety in buildings. The ventilation requirements in Table 2.5 are implicitly required by the Code.

The Code's Chapter 10, "Institutional Occupancies," includes the following text:

10-137. Hazardous Areas

10-1371. Any hazardous areas shall be safeguarded in accordance with Section 6-5. Hazardous areas include, but are not restricted to the following. Those areas accompanied by a dagger (†) in the list shall have both separation and a complete extinguishment system.

Boiler and heater rooms
Laundries
Kitchens
Repair Shops
Handicraft Shops
Employee locker rooms
† Soiled linen rooms
† Paint shops
† Rooms or spaces, including repair shops, used for the storage of combustible supplies and equipment in quantites deemed hazardous by the authority having jurisdiction.
† Trash collection rooms
Gift shops

10-1372. Laboratories shall be protected in accordance with the applicable standard listed in Appendix B. [7]

Appendix A, "Notes," provides the following explanatory material on the above text:

A-10-1371. For flammable liquid storage, reference should be made to NFPA Standard 30. Rooms in clinical laboratories in which automatic processing of specimens with flammable solvents is likely to take place when the equipment is unattended present a limited hazard which may be more readily protected through use of sprinklers connected to the domestic water supply. Provisons for the enclosure of rooms used for charging linen and waste chutes or for the rooms into which chutes empty are provided in Chapter 7. In addition to the fire-resistive cutoff of rooms into which linen chutes and waste chutes discharge, automatic sprinkler protection is considered essential. Provisions for the protection of storage facilities for flammable gases and oxygen are covered in NFPA 56A, Code for the Use of Inhalation Anesthetics, and NFPA 56F, Standard for Non-flammable Medical Gas Systems. [7]

The identification of NFPA Standard 56A in Appendix A simplies its incorporation into the Life Safety Code, as stated in Appendix B, "Referenced Publications." NFPA Standard 56A, "Standards for the Use of Inhalation Anesthetics (Flammable and Nonflammable)," specifies ventilation requirements for inhalation anesthetic gas use and storage. These are

the only requirements for hospital ventilation air within the Life Safety Code and are tabulated in Table 2.5 as requirements of the Code.

NFPA Standard 56A has the following scope:

12. Scope

1211. This standard states the composite methods whereby the hazards of fire, explosion, and electric shock attending the use of inhalation anesthetics may be reduced. It also specifies the design and procedures for operating rooms in which flammable agents shall not be used, the composite methods whereby the hazards of electric shock from power and lighting circuits may be mitigated, and also delineates safeguards in the use of compressed gas.

1212. Electric shock and compressed gas hazards, exist irrespective of whether the facility is designed for use of flammable agents or for the exclusive use of non-flammable agents.

1213. This standard is intended to provide requirements to protect against explosions or fires, electric shock, mechanical injury from compressed gases or compressed gas cylinders, or anoxia from erroneous gas connections without unduly limiting the activities of the surgeon or anesthesiologist.

1214. This principle, without minimizing any of the aforementioned dangers, recognizes that the physicians shall be guided by all the hazards to life that are inherent to surgical procedures carried out in anesthetizing locations.... 9

The following comments on its history, origin and development are included in NFPA Standard 56A:

When this standard was first published in 1941 the majority of inhalation anesthetics were administered with flammable agents, and fires and explosions in operating rooms occurred with disturbing frequency. Promulgation of this standard by the NFPA and the use of this standard by hospitals has lowered the incidence of such tragedies significantly.

Nonflammable inhalation anesthetics possessing relatively safe properties were developed during the 1950's. The increasing use of these agents has curtailed and in some institutions almost completely eliminated the use of flammable agents. This change in anesthetic practice has made it desirable to delineate standards of

construction and operation of rooms in locations where flammable agents never will be used. It must be emphasized that many safety recommendations pertain to hazards other than those related to fires and explosions, e.g., electric shock. It must also be recognized that these newer agents may possess toxicologic hazards to patients and personnel ....

This standard has been formulated in the belief that, although materials and mechanical equipment must be relied upon to the fullest possible extent for the mitigation of fire, explosion, and electric shock hazards, such physical safeguards are most effective only when augmented by safety precautions conscientiously applied by operating room and supporting personnel. This standard emphatically calls attention to the need for constant human diligence in the maintenance of safety practices, because of the peculiar intermixing of flammable anesthetic hazards and electric shock hazards, together with the mental strain in the environment of surgical operations ....

The original edition of No. 56 was in the form of an advisory pamphlet entitled "Combustible Anesthetics in Hospital Operating Rooms." In 1951 this was expanded and became "Safe Practices for Hospital Operating Rooms," and in 1962 it was renamed "Use of Flammable Anesthetics."

In 1970 it was expanded to include the use of nonflammable as well as flammable anesthetics. Other changes included the requirement for a dynamic line isolation monitor, special grounding procedures, and the revision of electrical safeguards to mitigate the hazard of electric shock in anesthetizing locations. The number was changed to No. 56A, and the title was changed to "Use of Inhalation Anesthetics." In 1971 ammendments included requirements for the equipotential grounding system, and the introduction of new designs for plugs and receptacles for use with the isolated power system. The 1972 edition included changes in testing requirements for antisatic materials, clarification of requirements for the Line Isolation Monitor, additional definitions, and new appendix material. [9]

For a few states, the only adopted standard specifying hospital ventilation requirements is the Life Safety Code. It must be emphasized that the ventilation requirements therein (i.e.,those of NFPA Standard 56A) are with respect to reducing the explosion and fire hazard associated with the storage and use of inhalation anesthetic gases. They are in no way

oriented toward protection of patients and staff from possible toxicological effects of these gases. That is, they are safety, not health, oriented.

Governmental Units

Table 2.6 summarizes standards adopted by five federal agencies and the 50 states, and Puerto Rico. The five federal agencies known to construct and operate their own hospitals are tabulated below. No other federal agencies are known to have internal hospital construction programs.

	Sub-Table
Department of Defense	
Department of the Air Force	2.6.1
Department of the Army	2.6.2
Department of the Navy	2.6.3
U. S. Department of Health, Education and Welfare	
Indian Health Service	2.6.4
Veterans Administration	2.6.5

Each of these agencies has adopted its own standard, vis-a-vis a national standard, as being more appropriate to its particular needs. There is no evidence of energy conservation measures incorporated into any of these standards.

At present, the 50 states and Puerto Rico can be classified as follows:

1. Adopts a Hill-Burton Standard (Table 2.2) (17 states and Puerto Rico):

   Alaska, Arizona, Delaware, Illinois, Iowa, Kansas, Michigan, Nevada, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Utah, Virginia, and West Virginia.

2. Adopts only an ASHRAE standard (Tables 2.3 and 2.4) (2 states)

   Maryland, and Nebraska. (Nebraska also requires conformance to NFPA Standard 56A)

3. Adopts only NFPA Life Safety Code (Table 2.5) (7 states):

   Georgia, Hawaii, Massachusetts, Oregon, South Carolina, Vermont, and Wyoming.

4. Adopts own standard (Tables 2.6.6 to 2.6.26) 19 states):

   Alabama*, Arkansas, California*, Connecticut*, Florida*, Idaho*, Indiana, Kentucky*, Minnesota*, Mississippi*, Missouri*, New Mexico*, North Carolina*, North Dakota*, Oklahoma, South Dakota*, Texas*, Washington,* and Wisconsin*. (The asterisked states also required conformance to NFPA Standard 56A)

5. Has no standard (5 states):

   Colorado, Louisiana, Maine, Montana, and Tennessee

The latest Hill-Burton standard is generally accepted by the health care community as specifying minimum acceptable hospital design and construction practice to ensure adequate patient and staff comfort and well being. An obvious conclusion from the above summary and from Tables 2.6.6 to 2.6.26 is that most states have adopted inadequate and/or outdated standards. In practice, however, since most hospital construction is federally funded, the latest Hill-Burton standard must be followed unless the state has adopted a more stringent standard. Even when Hill-Burton funding is not involved, it would be extremely difficult for the engineer to specify and justify a mechanical system providing less capability than the latest Hill-Burton standard.

Of the 33 states that have not adopted a Hill-Burton standard, four states have indicated that the latest Hill-Burton standard is informally applied (Minnesota, South Carolina, Tennessee, and Vermont), and four states have indicated plans to adopt a Hill-Burton standard (Colorado, Montana, Tennessee and Wisconsin). Nevada, which has adopted the 1969 Hill-Burton Standard by rule, plans to adopt an ASHRAE standard.

No significant energy conservation measures appear to be reflected in any of these state standards, irrespective of source.

JOINT COMMISSION ON ACCREDITATION OF HOSPITALS

A unique factor in the health care community is the Joint Commission on Accreditation of Hospitals (JCAH). The JCAH is dedicated "to the development of national standards of structure, function, staffing, and procedure for hospitals. All of these standards are directed toward the provision and maintenance of quality patient care." [1] JCAH standards and their interpretations form the basis by which the JCAH provides hospitals with consultation, education, evaluation and accreditation services on a fee basis. Requests for all JCAH services are voluntary, implying "a professionally motivated, voluntary commitment to self-evaluation and self-improvement" on on the part of the requesting hospital.

As stated in its certificate of incorporation, the formal purposes of the JCAH are:

1. *to establish standards for the operation of hospitals and other health-related facilities and services;*

2. *to conduct survey and accreditation programs that will encourage members of the health professions, hospitals, and other health-related facilities and services voluntarily:*

   a. *to promote high quality of care in all aspects in order to give patients the optimal benefits that medical science has to offer,*

   b. *to apply certain basic principles of physical plant safety and maintenance, and of organization and administration of function for efficient care of the patient, and*

   c. *to maintain the essential services in the facilities through coordinated effort of the organized staffs and the governing bodies of the facilities;*

3. *to recognize compliance with standards by issuance of certificates of accreditation;*

4. *to conduct programs of education and research and publish the results thereof, which will further the other purposes of the corporation, and to accept grants, gifts, bequests, and devices in support of the purposes of the corporation; and*

5. *to assume such other responsibilities and to conduct such other activities as are compatible with the operation of such standard-setting, survey and accreditation programs.* [1]

History

The history of the JCAH and its relationship to the health care community are summarized in the following paragraphs:

The Joint Commission on Accreditation of Hospitals is an outgrowth of the Hospital Standardization program established by the American College of Surgeons in 1918 to encourage the adoption of a uniform medical record format that would facilitate the accurate recording of the patient's clinical course. The American College of Surgeons recognized the need for a system of standardization thatwould provide a means of identifying those institutions devoted to the highest ideals of medicine.

Although the American College of Surgeons' standardization program was successful, it grew to be a financial burden on the College, and participation by other national professional organizations was solicited in order to continue the program. In 1951, an event occurred which was unique in the history of medicine: five major associations of North American medicine and hospitals jointly created an organization whose sole purpose was to encourage the voluntary attainment of uniformly high standards of institutional medical care. The founding members of the Joint Commission on Accreditation of Hospitals were the American College of Surgeons, the American College of Physicians, the American Hospital Association, the American Medical Association, and the Canadian Medical Association. The Canadian Medical Association continued its participation in the Joint Commission until 1959 when the Canadian Council on Hospital Accreditation activated its own program.

In 1965, Public Law 89-97 (Medicare) was enacted. Reference to the Joint Commission in this law represented the confidence of Congress in the ability of the health care sector to voluntarily assess the quality of care being provided. Written into the Medicare Act was the provision that the hospitals participating in that program were to maintain the level of patient care that had come to be recognized as the norm. The standards of the Joint Commission are specifically referred to in the law, and the Conditions of Participation for Hospitals, subsequently promulgated and published by the Social Security Administration, reflected in the 1965 standards of the Joint Commision.

One result of the 1965 Medicare legislation was the provision that hospitals accredited by the Joint Commission were automatically "deemed" to be in compliance with the federal Medicare Conditions of Participation and, thus, "deemed" to be eligible for participation in Medicare. (The 1972 Amendments to the Social Security Act, Public Law 92-603, provide for "validation" surveys of JCAH-accredited hospitals. This means that, while JCAH-accredited hospitals continue to be deemed eligible for participation in Medicare, the Secretary of the Department of Health, Education, and Welfare is authorized to validate JCAH findings, either on a selective sample basis or on the basis of substantial complaint.)[1]

Standards

The JCAH publishes an Accreditation Manual for Hospitals, which documents its current standards and their interpretations. Historically, the Manual has been published on an aperiodic basis; however , starting in 1978, it will be published annually on August 1 of each year, with the new requirements therein becoming effective for accreditation purposes on the succeeding January 1. This new schedule is intended to provide hospitals with publication predictability, an up-to-date Manual annually, and sufficient lead time to initiate necessary action to achieve compliance.

The JCAH standards are primarily oriented toward the operational aspects of the hospital, vis-a-vis design and construction. However, the Manual does include some general requirements with respect to design and construction, including ventilation. Reference is made to numerous National Fire Protection Association standards, including NFPA 101, "Life Safety Code." However, this is the only national standard described in this chapter that is explicitly cited by the Manual. All other references are generic; i.e., "applicable laws and regulations." [1]

Following are excerpts from the February 1978 edition of the Accreditation Manual for Hospitals that call out ventilation requirements. The Manual's format is a series of principles, each supported by one or more standards and an interpretation for each standard.

PRINCIPLE

THE HOSPITAL PREMISES SHALL BE STRUCTURALLY SAFE FOR ALL WHO USE THEM

STANDARD: The hospital buildings and grounds shall be designed, constructed, equipped, and furnished in a manner that protects the lives and ensures the physical safety of its patients, personnel, and visitors.

Interpretation: The hospital shall be designed, constructed equipped, and furnished in such a manner as to be in compliance with applicable building codes, fire prevention codes, state and/or federal occupational safety and health codes and standards, and the 1973 Life Safety Code of the National Fire Protection Association. Where there is a conflict in the applicable standards or codes, the more restrictive provisions shall prevail, unless documented equivalency satisfactory to the Joint Commission on Accreditation of Hospitals exists.

PRINCIPLE

THERE SHALL BE AN ORGANIZED DIETETIC SERVICE, WHICH SHALL EFFECTIVELY APPLY THE PRINCIPLES OF THE SCIENCE OF NUTRITION TO THE PREPARATION OF PALATABLE AND APPROPRIATE FOOD.

STANDARD: The dietetic service shall have adequate space, equipment and supplies to effect the efficient, safe, and sanitary operation of all functions assigned to it.

Interpretation: Facilities must be provided to fulfill the food service and dietetic needs of the hospital. The layout of the department, in combination with the type, size, and placement of equipment, should make possible efficient food preparation and distribution, and effective sanitation and safety. The food service area should be appropriately located and equippped. At least the following precautions shall be taken in the handling and preparation of food:. . . Control of lighting, ventilation, and ventilation, and humidity, in order to prevent both condensation of moisture and the growth of molds.

PRINCIPLE

THE HOSPITAL SHALL BE FUNCTIONALLY SAFE AND SANITARY FOR PATIENTS, HOSPITAL STAFF, AND VISITORS.

STANDARD: Comprehensive safety systems shall be installed, and practices, policies, and procedures instituted, to minimize hazards to patients, hospital staff, and visitors.

Interpretation: Handling and Storage of Flammable Gases and and Liquids . . . Enclosures in which flammable anesthetizing agents are stored shall be individually and continuously ventilated either by gravity or a mechanical means at a rate of not less than eight air changes per hour. There shall be a fresh-air inlet near the ceiling and an exhaust-air outlet near the floor . . . A relative humidity of at least 50% shall be maintained in anesthetizing areas, both flammable and nonflammable. The humidity rating shall be recorded every day anesthetizing agents are used.

Engineering and Maintenance. A scheduled preventive maintenance program shall be established for equipment related directly or indirectly to patient care and for building service equipment. To ensure safety and reliable performance, all equipment shall be kept clean, calibrated and adjusted, and in good repair. The written plan shall define the inspection interval for each individual item or category of equipment. Records shall be maintained to reflect the dates of inspection and maintenance as well as the status of all equipment, including the need for replacement and the individual notified of this need.

Installed equipment shall be located and mounted so as to minimize vibration and transmission of noise, and to facilitate servicing and maintenance. Wherever feasible, equipment shall be located in designated utility spaces or areas to minimize traffic of service personnel in hospital-function areas. Mechanical rooms shall not be used for material storage . . .

Patient and Personnel Safety Devices and Measures . . . Special safety measures shall be provided for areas of the hospital that present an unusual hazard to personnel or patients as follows . . . Rooms in which volatile and/or toxic chemicals are used shall be adequately ventilated and equipped with noncombustible fume hoods.

STANDARD: *Sanitation practices, policies, and procedures shall minimize health hazards to all patients, hospital staff and visitors*

Interpretation: A clean environment is essential in elminating health hazards. Of major concern are systems that involve water supply, ventilation, storage, and waste disposal. The relationship to infection control is stressed in the Infection Control section of this Manual.

Ventilation, Heating, and Other Mechanical Systems. All building service equipment, such as air-conditioning and ventilating systems and heating systems, shall be installed in accordance with applicable laws and regulations. All mechanical systems in the hospital shall be maintained in accordance with a written preventive maintenance program, with documentation of corrective measures instituted or completed.

The ventilation system shall provide a controlled, filtered air supply in designated critical areas, such as operating rooms, recovery rooms, delivery rooms, newborn nurseries and special care units. The air-handling system serving infectious isolation facilities shall be such that the attendant pressure patterns assure that potential airborne pathogens are not distributed to other areas of the hospital. Good ventilation must be assured for the clinical laboratory, dietetic services area, and laundry. The number of air exchanges per unit of time in any area shall be as specified by the authority having jurisdiction. Combustion and ventilation air for boiler, incinerator, or heater rooms shall be taken from and discharged to the outside.

PRINCIPLE

THERE SHALL BE AN EFFECTIVE INFECTION CONTROL PROGRAM WITHIN THE HOSPITAL

STANDARD: *There shall be an active hospital-wide infection control program.*

Interpretation: Because infections acquired in the hospital or brought into the hospital from the community are potential hazards for all persons having contact with the hospital, effective measures must be developed to prevent, identify, and control such infections.

The basic elements of the program shall include at least the following: . . . Preventive, surveillance, and control procedures relating to the inanimate hospital environment, including sterilization and disinfection practices, central service, housekeeping, laundry, engineering and maintenance, food sanitation, and waste management. Such procedures shall be evaluated, and revised as necessary, on a continuing basis . . .

An effective hospital infection control program should also include other elements that may be implemented to varying degrees depending on the facility and the services provided. These elements include but are not limited to: . . . Compliance with ventilation patterns and air exchange rates for operating rooms and isolation rooms of all types, as established by the authority having jurisdiction. This includes provision of rooms with a negative pressure system, to prevent potential airborne pathogens from being distributed to other patients and personnel from designated isolation cases, as well as the maintenance of a room at positive pressure relative to other areas of the hospital, as in the case of protective (reverse) isolation, when either of these facilities is required by the condition of the patient.

STANDARD: There shall be specific written infection control policies and procedures for all services throughout the hospital.

Interpretation: Linen and Laundry: . . . The laundry area should be planned, equipped, and ventilated so as to prevent the dissemination of contaminants. The ventilation system should include adequate intake, filtration, exchange rate, and exhaust in accordance with the local, state, and federal requirements....

PRINCIPLE

SERVICES PROVIDED BY THE HOSPITAL FOR OUTPATIENTS SHALL BE OF HIGH QUALITY AND SHALL BE RENDERED IN AN EFFECTIVE AND TIMELY MANNER.

STANDARD: Facilities for the outpatient service shall be conducive to the effective care of the patient.

Interpretation: Physical facilities of the service shall be structurally constituted and maintained in a manner that provides a clean, safe, and functional environment for patients and personnel . . .

The operating room should be so located that it does not directly connect with a corridor used for general through traffic. Entry and exit shall be controlled with respect to authorization of personnel, patients, and materials handling . . . An air-handling system shall be provided, the performance characteristics of which are in conformity with provisions of applicable codes.

PRINCIPLE

PATHOLOGY CONSULTATION AND SERVICES SHALL BE REGULARLY AND CONVENIENTLY AVAILABLE TO MEET THE NEEDS OF PATIENTS.

STANDARDS: There shall be sufficient space, equipment, and supplies within the pathology laboratory to perform the required volume of work with optimal accuracy, precision, efficiency, and safety.

Interpretation: The environment within the laboratory should be conducive to the optimal performance of personnel and equipment. The ventilation system should provide an adequate amount of fresh air and must be able to remove all toxic and noxious fumes.[1]

PRINCIPLE

THE HOSPITAL SHALL MAINTAIN A PHARMACEUTICAL SERVICE THAT IS CONDUCTED IN ACCORDANCE WITH ACCEPTED ETHICAL AND PROFESSIONAL PRACTICES AND ALL LEGAL REQUIREMENTS.

STANDARD: Space, equipment, and supplies shall be provided for the professional and administrative functions of the pharmaceutical service as requird, to promote patient safety thorugh the proper storage, preparation, dispensing, and adminstration of drugs.

Interpretation: Hospitals with an organized pharmaceutical service shall have the necessary space, equipment, and supplies for the storage, preparation (compounding, packaging, labeling), and dispensing of drugs. As appropriate, this shall include the preparation and dispensing of parenteral products and radiopharmaceuticals.

Drug storage and preparation areas within the pharmacy and throughout the hospital must be under the supervision of the director of the pharmaceutical service or his pharmacist-designee. Drugs must be stored under proper conditions of sanitation, temperature, light, moisture, ventilation, segregation, and security.

CONCLUSION

It is obvious that there are many standards promulgated by a multitude of regulatory agencies and standards organizations. They have different objectives, and there is a lack of common understanding and

interpretation. In this regard, infection control--a problem unique to hospitals and other health care facilities--is by far the most prominent issue. Again, however, it must be emphasized that the latest Hill-Burton Standard, which is specifically intended to provide a safe environment for both patients and staff, does take precedence over other standards for hospital design and construction. Nonetheless, the present plethora of standards is confusing and redundant.

Additionally, none of the standards described herein addresses energy conservation to any meaningful extent. The well-being of the patient takes precedence over all else. The time has come for energy, or the lack of energy, to become a consideration in tradeoff decisions in establishing hospital ventilation criteria.

It is apparent that the incorporation of energy conservation considerations cannot be accomplished adequately by merely adding some appropriate phrases to each of the existing codes and standards. It appears necessary to bring together the code writing and standard setting agencies and organizations to prepare a single document to which all can subscribe. The codification of ASHRAE standard 90-75 into the "Code for Energy Conservation in New Building Construction," described earlier in this chapter, may be a useful model for the process that needs to be undertaken. This project has an ongoing responsibility to develop recommendations as to development of a single, energy conservation oriented, hospital ventilation standard acceptable to the health care community.

References

1. Accreditation manual for hospitals. Chicago: Joint Commission on Accreditation of Hospitals, February 1978.

2. ASHRAE handbook and product directory: 1978 Applications. New York: The American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1978.

3. Code for energy conservation in new building construction. Building Officials and Code Administrators International, Inc., International Conference of Building Officials; National Conference of States on Building Codes and Standards; and Southern Building Code Congress International, Inc., December 1977.

4. DUNKLIN, E.W. and T.T. PUCK. The lethal effect of relative humidity on airborne bacteria. Journal of Experimental Medicine, 68: 87-101, February 1948.

5. GALSON, E. and K.R. GODDARD. Hospital air conditioning and sepsis control. ASHRAE Journal, 10: 33-41, July 1968.

6. GODDARD, K.R. Hospital ventilation system design. ASHRAE Journal, 8: 46-49, October 1966.

7. Life Safety Code. NFPA 101-1973. In National Fire Codes, Volume 9. Boston: National Fire Protection Association, 1975.

8. Minimum requirements of construction and equipment for hospital and health care facilities. U. S. Department of Health Service, Health Resources Administration. DHEW Publication No. (HRA) 74-4000), 1974.

9. Standard for the use of inhalation anesthetics (flammable and non-flammable). NFPA 56A-1973. In National Fire Codes Volume 4. Boston: National Fire Protection Association, 1975.

10. Standards for natural and mechanical ventilation. ASHRAE Standard 62-73 (ANSI B 194.1-1977). New York: The American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1973.

11. Thermal environmental conditions for human occupancy. ASHRAE Standard 55-74 (ANSI B 193.1-76). New York: The American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1974.

Figure 2.1

Matrix Format for Presentation of Hospital Ventilation Standards

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	-	-	-	-	-	-
Emergency Operating Room	-	-	-	-	-	-
Delivery Room	-	-	-	-	-	-
Nursery Suite	-	-	-	-	-	-
Recovery Room	-	-	-	-	-	-
Intensive Care	-	-	-	-	-	-
Patient Room	-	-	-	-	-	-
Patient Corridor	-	-	-	-	-	-
Isolation Room	-	-	-	-	-	-
Isolation Alcove	-	-	-	-	-	-
Examination Room	-	-	-	-	-	-
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	-	-	-	-	-	-
X-ray, Fluoroscopy Room	-	-	-	-	-	-
X-ray, Treatment Room	-	-	-	-	-	-
Physical Therapy and Hydrotherapy	-	-	-	-	-	-
Soiled Utility	-	-	-	-	-	-
Clean Utility	-	-	-	-	-	-
Autopsy	-	-	-	-	-	-
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	-	-	-	-	-	-
Bedpan Room	-	-	-	-	-	-
Bathroom	-	-	-	-	-	-
Janitors' Closet	-	-	-	-	-	-
Sterilizer Equipment Room	-	-	-	-	-	-
Linen and Trash Chute Rooms	-	-	-	-	-	-
Laboratory, General	-	-	-	-	-	-
Laboratory, Media Transfer	-	-	-	-	-	-
Food Preparation Centers	-	-	-	-	-	-
Warewashing	-	-	-	-	-	-
Dietary Day Storage	-	-	-	-	-	-
Laundry, General	-	-	-	-	-	-
Soiled Linen	-	-	-	-	-	-
Clean Linen	-	-	-	-	-	-
Anesthesia Storage	-	-	-	-	-	-
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	-
Clean Workroom	-	-	-	-	-	-
Unsterile Supply Storage	-	-	-	-	-	-

Tables 2.1 - 2.5: NATIONAL STANDARDS

FOOTNOTES

1. Air may not be recirculated unless filtered in this fashion: 2 filter beds; #1=25% and #2=90% efficiency. Filter efficiency will be checked according to ASHRAE Standard 52-68. A manometer will be installed across each filter bed.

2. This area may be vented by induction units: 1) if the units contain only a reheat coil, and 2) if only the primary air supplied from a central system passes through the reheat coil.

3. Recirculation will not be permitted unless 90% efficiency filters are used. ASHRAE dust spot method will be used to determine filter efficiency.

4. Recirculation will not be permitted unless 80% efficiency filters are used. ASHRAE dust spot will be used to determine filter efficiency.

5. Recirculation will not be permitted unless low efficiency, throw-away type filters are used.

6. Recirculation will not be permitted unless 95% efficiency filters are used. DOP method for testing filter efficiency will be employed.

7. Recirculation will not be permitted unless 99.97% efficiency filters are used. DOP method for testing filter efficiency will be employed.

8. Recirculation will not be permitted unless 50% efficiency filters are used. ASHRAE dust spot method of testing filter efficiency will be employed.

9. Supply air must be filtered by 90% efficiency filters. The DOP method of testing filter efficiencies will be used.

10. If 100% outside air is used, these quantities may be reduced to provide a minimum of 8 air changes per hour in the winter and 11-15 air changes per hour in the summer.

11. Recirculation will be permitted if and only if circulation is confined to a single area.

12. Recirculation will not be permitted unless the following filtration requirements are met: 2 filter beds, #1=25% and #2=90%; or if 100% outside air is used, one filter of the 25% variety may be used. All filters will be tested by the ASHRAE Standard 52-68.

13. If 100% outdoor air is used, total air changes can be reduced to 15 per hour.

TABLE 2.1: PROPOSED HILL-BURTON STANDARD

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5/15 (13)	25/15 (13)	No (1)	50-60	68-76
Emergency Operating Room	P	5/15 (13)	25/15 (13)	No (1)	50-60	68-76
Delivery Room	P	5	12	No (1)	50-60	70-76
Nursery Suite	P	5	12	No (1)	30-60	75
Recovery Room	P	2	6	No (1)	50-60	75
Intensive Care	P	2	6	No (1,2)	30-60	72-78
Patient Room	E	2	2	Optional	30-60	75
Patient Corridor	E	2	4	Optional	30-60	75
Isolation Room	E	2	6	No (2)	30-60	75
Isolation Alcove	E	2	10	No (2)	30-60	75
Examination Room	E	2	6	Optional	30-60	75
Medication Room	P	2	4	Optional	30-60	75
Pharmacy	P	2	4	Optional	30-60	75
Treatment Room	E	2	6	Optional	30-60	75
X-ray, Fluoroscopy Room	N	2	6	No	30-60	75
X-ray, Treatment Room	V	2	6	Optional	30-60	75
Physical Therapy and Hydrotherapy	N	2	6	Optional	30-60	75
Soiled Utility	N	2	10	No	30-60	75
Clean Utility	P	2	4	Optional	30-60	75
Autopsy	N	2	12	No	30-60	75
Workroom	N	2	10	No	30-60	75
Warefrigerated Body Holding Room	N	Optional	10	No	30-60	75
Toilet Room	N	Optional	10	No	30-60	75
Bedpan Room	N	Optional	10	No	30-60	75
Bathroom	N	Optional	10	No	30-60	75
Janitors' Closet	N	Optional	10	No	30-60	75
Sterilizer Equipment Room	N	Optional	10	No	30-60	75
Linen and Trash Chute Rooms	N	Optional	10	No	30-60	75
Laboratory, General	N	2	6	Optional	30-60	75
Laboratory, Media Transfer	P	2	4	No (1)	30-60	75
Food Preparation Centers	E	2	10	No	30-60	75
Warewashing	N	Optional	10	No	30-60	75
Dietary Day Storage	V	Optional	2	No	30-60	75
Laundry, General	V	2	10	No	30-60	75
Soiled Linen	N	Optional	10	No	30-60	75
Clean Linen	P	Optional	2	Optional	30-60	75
Anesthesia Storage	V	Optional	8	No	30-60	75
Central Medical and Surgical Supply						
Soiled Room	N	2	6	No	30-60	75
Clean Workroom	P	2	4	Optional	30-60	75
Unsterile Supply Storage	V	Optional	2	Optional	30-60	75

Supplemental Data: Proposed Hill-Burton Standard

Reference: Department of Health, Education, and Welfare, Public Health Service, Health Resources Administration, Division of Facilities Utilization. Minimum Requirements of Construction and Equipment for Hospitals and Medical Facilities. HRA Publication #78-14012.

Additional Requirements:

Table 2.1.1: Filter Efficiencies for Central Ventilation and Air Conditioning Systems in General Hospitals.

Area Designation	Minimum Number of Filter Beds	Filter Efficiencies (Percent) Filter Bed No. 1	Filter Bed No. 2
Sensitive Areas *	2	25	90
Patient Care, Treatment, Diagnostic, and Related Areas	2	25	90 **
Food Preparation Areas and Laundries	1	80	--
Administrative, Bulk Storage and Soiled Holding Areas	1	25	--

* Includes operating rooms, delivery rooms, nurseries, recovery rooms, and intensive care units.

** May be reduced to 80% for systems using all outdoor air.

All above filter efficiencies shall be average atmospheric dust spot efficiencies tested in accordance with ASHRAE Standard 52-68.

A manometer shall be installed across each filter bed serving sensitive areas** or central air systems.

The temperature in the Nursery Special Care Unit should be kept between 75 and 80 degrees Fahrenheit and the relative humidity should be kept between 30 and 60 percent.

The ventilation system for the anesthesia storage room shall conform to the requirements of NFPA standard 56 A.

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TABLE 2.2: 1974 HILL-BURTON STANDARD

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	25	No (1)	50-60	70-76
Emergency Operating Room	P	5	25	No (1)	50-60	70-76
Delivery Room	P	5	12	No (1)	50-60	70-76
Nursery Suite	P	5	12	No (1)	30-60	75
Recovery Room	P	2	6	No (1)	50-60	75
Intensive Care	P	2	6	No (1,2)	30-60	75-80
Patient Room	E	2	2	Optional	-	75
Patient Corridor	E	2	4	Optional	-	75
Isolation Room	E	2	6	No (2)	-	75
Isolation Alcove	E	2	10	No (2)	-	75
Examination Room	E	2	6	Optional	-	75
Medication Room	P	2	4	Optional	-	75
Pharmacy	P	2	4	Optional	-	75
Treatment Room	E	2	6	No (1)	-	75
X-ray, Fluoroscopy Room	N	2	6	Optional	-	75
X-ray, Treatment Room	E	2	6	Optional	-	75
Physical Therapy and Hydrotherapy	N	2	6	Optional	-	75
Soiled Utility	N	2	10	No	-	75
Clean Utility	P	2	4	Optional	-	75
Autopsy	N	2	12	No	-	75
Workroom	N	2	10	No	-	75
Warefrigerated Body Holding Room	N	Optional	10	No	-	75
Toilet Room	N	Optional	10	No	-	75
Bedpan Room	N	Optional	10	No	-	75
Bathroom	N	Optional	10	No	-	75
Janitors' Closet	N	Optional	10	No	-	75
Sterilizer Equipment Room	N	Optional	10	No	-	75
Linen and Trash Chute Rooms	N	Optional	10	No	-	75
Laboratory, General	N	2	6	Optional	-	75
Laboratory, Media Transfer	P	2	4	No (1)	-	75
Food Preparation Centers	E	2	10	No	-	75
Warewashing	N	Optional	10	No	-	75
Dietary Day Storage	E	Optional	2	No	-	75
Laundry, General	E	2	10	No	-	75
Soiled Linen	N	Optional	10	No	-	75
Clean Linen	P	2	2	Optional	-	75
Anesthesia Storage	E	Optional	8	No	-	75
Central Medical and Surgical Supply						
Soiled Room	N	2	6	No	-	75
Clean Workroom	P	2	4	Optional	-	75
Unsterile Supply Storage	E	2	2	Optional	-	75

Supplemental Data: 1974 Hill-Burton Standard

Reference: Department of Health, Education, and Welfare, Public Health Service, Health Resources Administration, Division of Facilities Utilization. Minimum Requirements of Construction and Equipment for Hospitals and Medical Facilities. HRA Publication #74-4000. U. S. Government Printing Office, Washington D. C. 1974.

Additional Requirements:

Table 2.2.1: Filter Efficiencies for Central Ventilation and Air Conditioning Systems in General Hospitals.

Area Designation	Minimum Number of Filter Beds	Filter Efficiencies (Percent) Filter Bed No. 1	Filter Bed No. 2
Sensitive Areas *	2	25	90
Patient Care, Treatment, Diagnostic, and Related Areas	2	25	90 **
Food Preparation Areas and Laundries	1	80	--
Administrative, Bulk Storage and Soiled Holding Areas	1	25	--

* Includes operating rooms, delivery rooms, nurseries, recovery rooms, and intensive care units.

** May be reduced to 80% for systems using all outdoor air.

All above filter efficiencies shall be average atmospheric dust spot efficiencies tested in accordance with ASHRAE Standard 52-68.

A manometer shall be installed across each filter bed serving sensitive areas** or central air systems.

The temperature in the Nursery Special Care Unit should be kept between 75 and 80 degrees Fahrenheit and the relative humidity should be kept between 30 and 60 percent.

The ventilation system for the anesthesia storage room shall conform to the requirements of NFPA standard 56 A.

TABLE 2.3: ASHRAE STANDARD 62-73

Area Designation	Relative Pressure	Minimum Cubic Feet Per Minute Per Person	Recommended Cubic Feet Per Minute Per Person	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	-	20	-	-	-	-
Emergency Operating Room	-	20	-	-	-	-
Delivery Room	-	20	-	-	-	-
Nursery Suite	-	-	-	-	-	-
Recovery Room	-	15	-	-	-	-
Intensive Care	-	-	-	-	-	-
Patient Room	-	10	15-20	-	-	-
Patient Corridor	-	20	25-30	-	-	-
Isolation Room	-	-	-	-	-	-
Isolation Alcove	-	-	-	-	-	-
Examination Room	-	-	-	-	-	-
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	-	-	-	-	-	-
X-ray, Fluoroscopy Room	-	-	-	-	-	-
X-ray, Examination Room	-	-	-	-	-	-
Physical Therapy and Hydrotherapy	-	15	20-25	-	-	-
Soiled Utility	-	-	-	-	-	-
Clean Utility	-	-	-	-	-	-
Autopsy	-	30	40-50	-	-	-
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	-	20	30-50	-	-	-
Bedpan Room	-	-	-	-	-	-
Bathroom	-	-	-	-	-	-
Janitors' Closet	-	-	-	-	-	-
Sterilizer Equipment Room	-	-	-	-	-	-
Linen and Trash Chute Room	-	-	-	-	-	-
Laboratory, General	-	-	-	-	-	-
Laboratory, Media Transfer	-	-	-	-	-	-
Food Preparation Centers	-	35	35	-	-	-
Warewashing	-	35	35	-	-	-
Dietary Day Storage	-	35	35	-	-	-
Laundry, General	-	-	-	-	-	-
Soiled Linen	-	-	-	-	-	-
Clean Linen	-	-	-	-	-	-
Anesthesia Storage	-	-	-	-	-	-
Central Medical and Surgical Supply:						
Soiled room	-	-	-	-	-	-
Clean Workroom	-	-	-	-	-	-
Unsterile Supply Storage	-	-	-	-	-	-

Supplemental Data: ASHRAE Standard 62-73

Reference: ASHRAE Standard 62-73 (ANSI B 194.1-1977). Standards for Natural and Mechanical Ventilation. ASHRAE Inc. New York, 1973.

Additional Requirements: In no case shall the outdoor air quantity be less than 5 CFM per person.

Table 2.3.1: Maximum Allowable Contaminant Concentrations for Ventilation Air.

Contaminant	Annual Average (Arithmetic Mean) ug/m^3	Short-Term level (Not to be exceeded More than once a Year) ug/m^3	Averaging Period (hr)
Particulates	60 *	150 *	24
Sulfur Oxides	80	400	24
Carbon Monoxide	20,000	30,000	8
Photochemical Oxidant	100	500	1
Hydrocarbons (not including methane)	1,800	4,000	3
Nitrogen Oxides	200	500	24
Odor		Essentially Unobjectionable **	

* Federal criteria for U.S. by 1975.

** Judged unobjectionable by 60% of a panel of 10 untrained subjects.

Recirculation will be permitted if the air meets the above criteria.

TABLE 2.4: ASHRAE 1978 HANDBOOK STANDARD

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5/15 (13)	25/15 (13)	No (1)	50-60	68-76
Emergency Operating Room	P	5/15 (13)	25/15 (13)	No (1)	50-60	68-76
Delivery Room	P	5	12	No (1)	50-60	68-76
Nursery Suite	P	5	12	No (1)	30	75
Recovery Room	P	2	6	No (1)	50-60	75
Intensive Care	P	2	6	No (1,2)	30-60	75-80
Patient Room	E	2	2	Optional	30-50	75
Patient Corridor	E	2	4	Optional	30-50	75
Isolation Room	E	2	6	No (2)	30	75
Isolation Alcove	E	2	10	No (2)	30	75
Examination Room	E	2	6	Optional	30	75
Medication Room	P	2	4	Optional	30	75
Pharmacy	P	2	4	Optional	30	75
Treatment Room	E	2	6	Optional	30	75
X-ray, Fluoroscopy Room	N	2	6	No	40-50	75-80
X-ray, Treatment Room	E	2	6	Optional	30	75
Physical Therapy and Hydrotherapy	N	2	6	Optional	30	80
Soiled Utility	N	2	10	No	30	75
Clean Utility	P	2	4	Optional	30	75
Autopsy	N	2	12	No	30	75
Workroom	-	-	-	-	30	75
Warefrigerated Body Holding Room	N	Optional	10	No	30	75
Toilet Room	N	Optional	10	No	30	75
Bedpan Room	N	Optional	10	No	30	75
Bathroom	N	Optional	10	No	30	75
Janitors' Closet	N	Optional	10	No	30	75
Sterilizer Equipment Room	N	Optional	10	No	30	75
Linen and Trash Chute Rooms	N	Optional	10	No	30	75
Laboratory, General	N	2	6	Optional	30	75
Laboratory, Media Transfer	P	2	4	No (1)	30	75
Food Preparation Centers	E	2	10	No	30	75
Warewashing	N	Optional	10	No	30	75
Dietary Day Storage	E	Optional	2	Optional	30	75
Laundry, General	E	2	10	No	30	75
Soiled Linen	N	Optional	10	No	30	75
Clean Linen	P	Optional	2	Optional	30	75
Anesthesia Storage	E	Optional	8	No	30	75
Central Medical and Surgical Supply						
Soiled Room	N	2	6	No	30	75
Clean Workroom	P	2	4	Optional	30	75
Unsterile Supply Storage	E	Optional	2	Optional	30	75

Supplemental Data: ASHRAE 1978 Handbook Standard

Reference: ASHRAE Handbook and Product Directory 1978 Applications. ASHRAE Inc. New York, 1978

Additional Requirements: Medium efficiency grade filters of at least 80% efficiency (certified by an independent testing agency using the ASHRAE Filter Test Standard 52-68) will suffice for central 100% outdoor air systems serving patient rooms.

Filters with an efficiency of at least 90% (using ASHRAE 52-68) should be used with central systems that recirculate and redistribute the air to the various patient rooms.

To control odor that is associated with some cases, activated charcoal filters or additional ventilation may be required in a central recirculating system.

High efficiency filters having at least 90% (ASHRAE 52-68) efficiencies should be used on the air supply systems serving surgical suites, obstetrical suites, nurseries, reverse isolation rooms, and intensive care rooms. Some agencies require 95% efficiencies tested by the DOP method.

Table 2.4.1: Filter Efficiencies for Central Ventilation and Air Conditioning Systems in General Hospitals.

Area Designation	Minimum Number of Filter Beds	Filter Efficiencies (Percent) Filter Bed No. 1	Filter Bed No. 2
Sensitive Areas *	2	25	90
Patient Care, Treatment, Diagnostic, and Related Areas	2	25	90 **
Food Preparation Areas and Laundries	1	80	--
Administrative, Bulk Storage and Soiled Holding Areas	1	25	--

* Includes operating rooms, delivery rooms, nurseries, recovery rooms, and intensive care units.

** May be reduced to 80% for systems using all outdoor air.

All above filter efficiencies shall be average atmospheric dust spot efficiencies tested in accordance with ASHRAE Standard 52-68.

A manometer shall be installed across each filter bed serving sensitive areas** or central air systems.

The temperature in the Nursery Special Care Unit should be kept between 75 and 80 degrees Fahrenheit and the relative humidity should be kept between 30 and 60 percent.

The ventilation system for the anesthesia storage room shall conform to the requirements of NFPA standard 56 A.

TABLE 2.5: LIFE SAFETY CODE

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	25	No (3)	≥ 50	68-75
Emergency Operating Room	P	5	25	No (3)	≥ 50	68-75
Delivery Room	P	5	25	No (3)	≥ 50	65-75
Nursery Suite	-	-	-	-	-	-
Recovery Room	-	-	-	-	-	-
Intensive Care	-	-	-	-	-	-
Patient Room	-	-	-	-	-	-
Patient Corridor	-	-	-	-	-	-
Isolation Room	-	-	-	-	-	-
Isolation Alcove	-	-	-	-	-	-
Examination Room	-	-	-	-	-	-
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	-	-	-	-	-	-
X-ray, Fluoroscopy Room	-	-	-	-	-	-
X-ray, Treatment Room	-	-	-	-	-	-
Physical Therapy and Hydrotherapy	-	-	-	-	-	-
Soiled Utility	-	-	-	-	-	-
Clean Utility	-	-	-	-	-	-
Autopsy	-	-	-	-	-	-
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	-	-	-	-	-	-
Bedpan Room	-	-	-	-	-	-
Bathroom	-	-	-	-	-	-
Janitors' Closet	-	-	-	-	-	-
Sterilizer Equipment Room	-	-	-	-	-	-
Linen and Trash Chute Rooms	-	-	-	-	-	-
Laboratory, General	-	-	-	-	-	-
Laboratory, Media Transfer	-	-	-	-	-	-
Food Preparation Centers	-	-	-	-	-	-
Warewashing	-	-	-	-	-	-
Dietary Day Storage	-	-	-	-	-	-
Laundry, General	-	-	-	-	-	-
Soiled Linen	-	-	-	-	-	-
Clean Linen	-	-	-	-	-	-
Anesthesia Storage	E	-	8	No	≥ 50	65-75
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	-
Clean Workroom	-	-	-	-	-	-
Unsterile Supply Storage	-	-	-	-	-	-

Supplemental Data: Life Safety Code

Reference: National Fire Protection Association. Code for Safety to Life from Fire in Buildings and Structures, NFPA 101-1973. Boston 1973.

Additional Requirements: NFPA Codes 56A, B, and C.

High efficiency filters (99.7%) shall be used in areas where highly infectious or radioactive material is used.

TABLE 2.6: STANDARDS ADOPTED BY GOVERNMENTAL UNITS

This table summarizes hospital ventilation and thermal standards adopted by federal agencies for their respective hospital construction programs, and by each of the 50 states and by Puerto Rico for hospital construction within their jurisdiction. The table is in two parts:

1. A status summary of the standards of each governmental unit, including authority for the standard (reference); the specific standard adopted, and additional requirements imposed.

2. A set of tables (Tables 2.6.1 to 2.6.28) summarizing the ventilation and thermal requirements of each governmental unit that adopts its own standard. Footnotes for these tables are found immediately preceeding Table 2.1.

STATUS SUMMARY OF STANDARDS ADOPTED BY GOVERNMENTAL UNITS

Table

DEPARTMENT OF THE AIR FORCE 2.6.1

Reference: Department of Defense, Department of the Air Force, Facilities Division. Air Force Manual 88-15, Air Force Design Manual, Criteria and Standards for Air Force Construction.

Standard: Agency.

Additional Requirements:

--Mechanical ventilation may be provided for any space where it is not feasible or possible to provide natural ventilation for human comfort.

--Air Filters.

1. Filters classified as roughing (65%) shall be tested by the NBS Dust Spot Test Method using Cotrell Dust.

2. Medium (30%-90%) high efficiency (90%-99%) filters are generally tested by the NBS Dust Spot Test Method using atmospheric dust.

3. Ultra high efficiency filters (99.97%) are rated by the DOP test.

4. All filters will conform to class 1 or 2 U.L. incorporated.

--Critical air handling systems (those systems serving surgery, delivery, nursery, urology, and ICU) shall carry a minimum 25% outside air.

--Non-critical air handling systems (those areas of the hospital not mentioned above) shall be supplied with a minimum of 15% outside air based on 15 cfm/person.

--Surgery, obstetrical, nursery, urology, and ICU will require filters in the following sequence.

1. Roughing filter of 70% minimum efficiency.

2. High efficiency filter of 80-85% minimum efficiency tested by the DOP test.

3. Ultra high efficiency filter.

--Patient room systems will require filters in the following sequence.

1. Combination outside air intake roughing filter, 70% minimum efficiency and a medium filter, 80% minimum efficiency.

--Isolation rooms used for burn patients will require a combination ultra high efficiency filter and a booster fan.
--The clinical, administrative, dining and kitchen areas will require a combination roughing filter 70% minimum efficiency and a medium filter of 80% minimum efficiency, upstream of AHU coils.
--Filters with an efficiency of not less than 95% (DOP) shall be used as the final filter for all air supplied to sterile corridors serving critical areas.

DEPARTMENT OF THE ARMY 2.6.2

Reference: Department of Defense, Department of the Army, Office of the Chief of Engineers. Engineering and Design, Interior Mechanical Design for Army Medical Facilities.

Standard: Agency.

Additional Requirements:
--Supply air to the operating, delivery, and nursery rooms shall be filtered by two beds, #1=90% and #2=99.97%. Filter efficiencies will be measured by the DOP method of testing filter efficiencies.
--Air supplied to the recovery and intensive care units, shall be filtered by one bed of 90% efficiency filters. Filter efficiency based on the DOP method of testing filter efficiency.
--Air supplied to areas not mentioned in the above filtration requirements, shall be filtered by one bed of 78% efficiency filters. Filter efficiency will be determined by using ASHRAE Standard 52-76.
--Air supplied to the media transfer room of the laboratory, shall be filtered by two beds of filters, #1=78% and #2=95% efficient. Filter efficiency will be determined by using the DOP testing method.
--The ventilation system for anesthesia storage room shall conform to the requirements of NFPA Standard 56A.

Table

DEPARTMENT OF THE NAVY 2.6.3

Reference: Department of Defense, Department of the Navy, Naval Facilities Engineering Command. Medical Facilities Layout Plates.

Standard: Agency.

Additional Requirements: --Air supplied to all areas shall be filtered by two beds, #1=25% and #2=80%, except in the following areas in which one filter bed of 99.97% efficiency shall be added: operating room, delivery room, nursery, recovery and ICU.

INDIAN HEALTH SERVICES 2.6.4

Reference: Indian Health Service.New Hospital. Heating, Ventilating, and Air Conditioning Design Criteria-Minimum Standards.

Standard: Agency.

Additional Requirements: --All supply air will be filtered by two beds of filters, #1=25% and #2=90% efficient. Filter efficiency will be determined by using the ASHRAE Standard 52-68
--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.

VETERANS ADMINISTRATION 2.6.5

Reference: Veterans Administration, Office of Construction, Energy Engineering Division. Revised Heating, Ventilating, and Air Conditioning Design Criteria.

Standard: Agency.

Additional Requirements: --The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.

ALABAMA 2.6.6

Reference: Alabama State Board of Health, Rules, Regulations, and Standards for Hospitals with Licensure Law and Guidelines and Recommendations. Adopted December 21, 1966; last revised and effective December 18, 1970.

Standard: State .

--The patient room shall be ventilated in such a manner as to supply fresh air and to prevent accumulation of objectionable odors.
--All inside rooms shall be ventilated by louvers, wall vents, or undercut in doors, and by windows, gravity vents or by mechanical means so as to prevent offensive odors from entering other parts of the building.
--The food service area shall be ventilated in such a manner that will maintain comfortable working conditions, remove objectionable odors and fumes and prevent excessive condensation.
--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.

ALASKA 2.2

Reference: State of Alaska, Department of Health and Social Services, Division of Public Health, Environmental Health Section. Health Facilities Certification and Licensing. Adopted July 1977.

Standard: 1974 Hill-Burton Standard, by reference.

Additional Requirements:
--The heating system shall be capable of maintaining temperatures adequate for the comfort and protection of all patients at all times.
--Kitchens, laundries, toilet rooms, and utility rooms shall be ventilated by windows or mechanical means to control temperatures and offensive odors.
--Eating places shall have sufficient ventilation to keep free of excessive heat, steam, condensation, vapors, smoke, and fumes.

ARIZONA 2.2

Reference: State of Arizona, Department of Health Services of Planning and Resources. Health Care Institutions: Licensure. Effective January 1974.

Standard: 1974 Hill-Burton Standard, by reference.

Additional Requirements:
--Heating, cooling, and ventilating systems shall be appropriate for the welfare and comfort of the patients and employees at all times.
--All gas heaters will be properly vented to the outside.
--Each patient room shall have one window with unobstructed natural light and ventilation.

Table

ARKANSAS 2.6.7

Reference: Arkansas State Department of Health. Rules and Regulations for Hospitals and Related Institutions in Arkansas. Adopted in 1961; last amended 1975.

Standard: State.

Additional Requirements:

--The total air changes in the pharmacy shall be proper.

--The ventilation system serving the operating room, delivery room, nursery, isolation rooms, and the laboratory sterile rooms, and where recirculation is not permitted, shall be equipped with two filter beds on the supply duct. #;=30% and #2=90% efficiency. The NBS method of testing filter efficiency will be used.

--The ventilation system serving the laboratory shall be equipped with 80% efficiency filters. The NBS method of testing filter efficiency will be used.

CALIFORNIA 2.6.8
2.6.9

Reference: State of California, Health and Welfare Agency, Department of Health. Drafted December 1976.

Standard: State [Table 2.6.8: 100% Outside Air; Table 2.6.9: not 100% outside air].

Additional Requirements:

--Rooms in areas where excessive heat or moisture is generated, where objectionable odors or dust are present, or where flammable or toxic gases may accumulate, which are used by hospital personnel or patients shall be provided with exhaust ventilation to change the air a minimum of 10 times per hour.

--Natural ventilation through windows or other openings such as louvers shall be considered as supplemental to the required mechanical ventilation systems.

--Air shall be introduced at the cleanest areas and removed from the dirtiest areas in order to reduce the changes of airborne cross infection.

--A manometer shall be installed across each filter bed serving central air systems.

--80% efficiency filters shall be used on air supply ducts. A prefilter is recommended.

--Two beds of 90% efficiency filters shall be used on all supply air systems in 100% outside air systems serving operating room, delivery, and the nursery.
--100% outside air. Where air conditioning is listed as optional, it will be assumed that no minimum outside standard exists.
--Filter efficiencies shall be certified by the manufacturer and shall be based on ASHRAE Standard 52-68 or the DOP (dioctyl phthalate) test method when specifically set forth in these standards.
--All air distribution sytems serving sensitive areas, including operating rooms, delivery rooms, nurseries, isolation rooms and laboratory media preparation rooms, intensive care units, cardiovascular catheterization laboratories and recirculated central air systems serving other hospital areas, shall be equipped with one filter bank, and shall have a minimum efficiency of 90%.
--Filters for burn care centers shall be HEPA filters having a 99.9% efficiency.
--Chemical air cleaners of the spray chamber type utilizing a bacterio-static non-toxic solution may be used in lieu of filter bank #2. Such cleaners shall have installed as an integral part a filter designed to provide a unit efficiency of 90% and shall prevent mechanical carry over or precipitation of chemicals when operated at rated capacity.
--Air handling units serving administrative, maintenance shops, and general storage areas only may be equipped with a filter bank of 25% efficiency.
--Evaporative coolers and make-up units serving one room only of kitchens or laundries shall be equipped with 25% efficient filters downstream of the evaporative cooling section.
--The air from dining areas may be used to ventilate the food preparation areas only after it has passed through a filter with 80% average efficiency.
--Floor surfaces in occupied spaces above such rooms (boiler room, heater room, electrical equipment room) should not exceed a temperature of 29.4 C and suitable insulation may be required.
--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A-1973.

	Table
COLORADO	2.2
Reference:	State of Colorado, Department of Health, Design and Construction, Medical Care Licensing and Certification Division. General Hospitals-Chapter IV. Adopted September 15, 1976; effective January 11, 1977.
Standard:	None. (Plans to adopt the 1974 Hill-Burton Standard).
Additional Requirements:	--Rooms for preparing and serving food and washing utensils shall be well ventilated. --The flow of air in the central medical-surgical supply shall be from the clean areas towards the exhaust in the soiled area. Exhausts shall be placed over the sterilizers to prevent condensation on walls and ceilings. --The soiled utility room shall be provided with continuous exhaust to the outside. --The dietary day storage room shall be well ventilated. --Adequate ventilation shall be provided to the pharmacy.
CONNECTICUT	2.6.10
Reference:	State of Connecticut, Department of Health. Short Term Hospitals General and Special.
Standard:	State.
Additional Requirements:	--See specifications in Table 2.2.1. Filter Efficiencies for Central Ventilation and Air Conditioning Systems in General Hospitals. --The ventilation systems for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A. --A pressure differential device shall be installed across each filter bed serving sensitive areas of central air systems. --Boiler rooms shall be provided with sufficient outdoor air to maintain combustion rates of equipment.
DELAWARE	2.2
Reference:	State of Delaware, Department of Health and Social Services, Division of Public Health. Office of Health Facilities Licensing and Certification. Laws, Rules and Regulations Governing the Licensing of Hospitals and the Development, Establishment and the Enforcement of Standards for the Construction, Maintenance and Operation of Hospitals in the State of Delaware. Adopted

Table

July 10, 1970; last amended, January 28, 1974.

Standard: 1974 Hill-Burton Standard, adopted by reference.

Additional Requirements: --None.

FLORIDA 2.6.11 2.6.12

Reference: State of Florida, Department of Health and Rehabilitative Services, Office of Licensure and Certification. Adopted January 1, 1977.

Standard: State [Table 2.6.11: Low Filtration; Table 2.6.12: High Filtration].

Additional Requirements:
--Humidity shall be in the comfort zone for all patient areas except as noted on Table 2.6.11 and 2.6.12.
--All outside air shall be filtered via 80% efficiency filters. ASHRAE dust spot method of testing filter efficiency shall be used.
--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A-1973.

GEORGIA 2.5

Reference: State of Georgia, Department of Human Resources, Office of Regulatory Services, Standards and Licensing Unit. Revised September 1974.

Standard: NFPA Standard 101, adopted by reference.

Additional Requirements: --None.

HAWAII 2.5

Reference: State of Hawaii, Department of Health. Public Health Regulations, Chapter 12-Hospitals. Adopted March 19, 1973; effective May 15, 1973.

Standard: NFPA Standard 101, adopted by reference.

Additional Requirements: --None.

	Table
IDAHO	2.6.13
Reference:	State of Idaho, Department of Health. Rules, Regulations, and Minimum Standards for Hospitals in Idaho. 1963 Edition.
Standard:	State.
Additional Requirements:	--The ventilation system for anesthesia storate rooms shall conform to the requirements of NFPA Standard 56A. (latest edition). --Patient rooms shall be ventilated by natural or mechanical means to assure a fresh air supply. --Air supplied to anesthetizing areas shall be humid enough to prevent static charge.
ILLINOIS	2.2
Reference:	State of Illinois, Department of Public Health, Office of Health Facilities and Quality of Care, Hospitals and Ambulatory Surgical Treatment Center Section. Hospital Licensing Act and Requirements. Adopted July 1, 1953 and last amended October 1, 1977.
Standard:	1974 Hill-Burton Standard, adopted by rule .
Additional Requirements:	--None.
INDIANA	2.6.14
Reference:	State of Indiana, State Board of Health, Division of Hospital and Institutional Services. Indiana State Board of Health, Regulations for General and Special Hospitals-HHL 42. Effective December 18, 1977.
Standard:	State.
Additional Requirements:	--The hemodialysis and/or protective isolation rooms shall be ventilated in the following manner: A negative pressure must be maintained, with 2 air changes of outdoor air per hour with a total of 6 air changes per hour. --A filter with 90% efficiency shall be installed in the air supply system at its entrance to the laboratory media transfer room, except where laminar flow hoods or equivalent devices are used. --A manometer shall be installed across each filter bed.
IOWA	2.2
Reference:	State of Iowa, Iowa State Department of Health, Health Facilities Division. Hospital Rules and Standards. Adopted October 10, 1976; effective January 5, 1977.
Standard:	1974 Hill-Burton Standard, adopted by rule.

Additional Requirements:
--The heating plant shall be adequate to maintain a cold weather temperature of 70° F throughout the building and a higher temperature where required.
--Kitchens, bathrooms and service rooms shall be so located and ventilated by window or mechanical means to prevent offensive odors from entering patient rooms and the public halls.

KANSAS 2.2

Reference: State of Kansas, Department of Health and Environment, Medical Facilities Licensure Section, Bureau of Medical-Dental Health.

Standard: 1974 Hill-Burton Standard, adopted by rule.

Additional Requirements:
--None.

KENTUCKY 2.6.15

Reference: Commonwealth of Kentucky, Department for Human Resources, Bureau for Health Services, Center for Comprehensive Health Systems Development, Standards Development Section, Kentucky Health Facilities and Health Services, Certificate of Need and Licensing Board.

Standard: State.

Additional Requiremenst:
--The operating room, nursery suite, delivery room, isolation room, have the air supply filtered by two beds of filters, #1=30%, #2=90%, based on the NBS dust method.
--Ventilation systems serving sensitive areas such as, operating rooms, delivery rooms, nurseries, isolation rooms and laboratory sterile rooms, and circulated central air systems serving other hospital areas, shall be equipped with a minimum of two filter beds, #1=30%, and #2=90%.
--Central air systems using 100% outdoor air shall be provided with filters rated at 80 % efficiency.
--All filter efficiencies shall be based on the NBS Dust Spot Test Method with Atmospheric Dust.
--A manometer shall be installed across each filter bed serving central air systems.
--The ventilation system serving anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.

Table

LOUISIANA . . . . . NA

Reference: State of Louisiana, Louisiana State Department of Hospitals. Rules, Regulations and Minimum Standards Governing Hospitals and the Hospital Licensing Law. Adopted April 24, 1962; promulgated by the Hospital Licensing Council May 10, 1962.

Standard: None.

Additional Requirements:
--The nursery suite shall be maintained with a temperature of 75° F.
--All heating systems shall be constructed, maintained and operated in a manner to provide a comfortable temperature for patients and personnel.
--All rooms in general use shall be provided with adequate ventilation.

MAINE 2.5

Reference: State of Maine, Department of Human Services, Division of Hospital Licensing. Regulations for the Licensure of General and Specialty Hospitals in the State of Maine. Adopted July 1972.

Standard: None.

Additional Requirements: --None

MARYLAND 2.3
2.4

Reference: State of Maryland, Maryland State Department of Health and Mental Hygiene. 10.02-04-Standards and Regulations for Acute General Hospitals and Special Hospitals. Originally adopted December 19,1946; last revised 1972.

Standard: ASHRAE Standard 62-73 or ASHRAE 1974 Handbook*.

Additional Requirements: --None

* It is assumed that the state was refering to one of the ASHRAE standards when it stated, "All governing laws, ordinances, codes, etc. shall be met, together with the applicable minimum standards of ASHVE."

	Table
MASSACHUSETTS	2.5
Reference:	Commonwealth of Massachusetts, Department of Public Health, Division of Hospitals and Ambulatory Care. Licensure Rules and Regulations for Hospitals in Massachusetts. 1972.
Standard:	NFPA Standard 101, adopted by rule.
Additional Requirements:	--The heating plant including boiler, connecting pipes or ducts, radiators, space heaters, grilles and diffusors shall be so designed and maintained as to provide environmental warmth to insure adequate comfort and temperature conditions satisfactory to the Department.
MICHIGAN	2.2
Reference:	State of Michigan, Department of Public Health Bureau of Health Care Administration. Licensing of Hospitals Act 17. Adopted 1968, last revised 1975.
Standard:	1974 Hill-Burton Standard, adopted by reference*.
Additional Requirements:	--None.
	*The Director of Public Health "shall adopt such standards, rules and regulations as are necessary to enable the state or individual hospitals or both to qualify for federal funds provided to assist with patient care or for construction or remodeling of facilities. The standards, rules and regulations for the operation and maintenance of hospitals shall not be less than is required for the certification of hospitals under Public Law 89-97 and standards, rules and regulations relating to the construction or remodeling shall not be less than those required for federal assistance under Public Law 88-43 ."
MINNESOTA	2.6.16
Reference:	State of Minnesota, Minnesota State Board of Health, Division of Health Facilities. Minnesota Statutes and Regulations of the Minnesota State Board of Health for the Construction, Equipment, Maintenance, Operation and Licensing of Hospitals. Effective August 13, 1955; 1974 edition.
Standard:	State*.

Additional Requirements:
--All outside air shall be tempered and filtered.
--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A-1954.

*Informally applies 1974 Hill-Burton Standard.

MISSISSIPPI 2.6.17

Reference: State of Mississippi, Mississippi Commission on Hospital Care. Mississippi Hospitals. Adopted March 12, 1973; effective May 15, 1973.

Standard: State.

Additional Requirements:
--All areas open to patients shall have at least 2 air changes per hour.
--All hospitals shall be so located to be reasonably free of undue noises, smoke, dust or foul odors, and should not be located adjacent to railroads, freight yards, schools, childrens' playgrounds, or airports, industrial plants, or disposal plants.
--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.

MISSOURI 2.6.18

Reference. State of Missouri, Department of Social Services, Division of Health, Bureau of Health Facilities Planning and Construction. Missouri Hospital Licensing Law Regulations and Codes. Adopted 1960; reaffirmed 1974.

Standard: State.

Additional Requirements:
--The operating and delivery rooms shall be provided with fresh filtered air.
--The patient rooms shall be provided with natural ventilation.
--The heating system shall be capable of maintaining 70° F except as noted.
--Compliance is urged with the 1974 Hill-Burton Standard (Table 2.2)
--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.

	Table
MONTANA	2.2
Reference:	State of Montana, Department of Health and Environmental Sciences, Division of Hospital and Medical Facilities.
Standard:	None (Proposes to adopt 1976 Hill-Burton Standard).
Additional Requirements:	--None.
NEBRASKA	2.4
Reference:	State of Nebraska, Department of Health, Section of Hospital and Medical Facilities Designated Agency. Regulations and Standards for Hospitals. Effective February 4, 1976.
Standard:	ASHRAE 1974 Handbook*.
Additional Requirements:	--Heating plant should be adequate to maintain a temperature of 80° F in severe weather and capable of maintaining a temperature of 90° F in nurseries. --At all times the building shall be adequately ventilation. Kitchen, bathroom, and service room shall be so located and ventilated by window or mechanical means through a vent leading directly to the outside so as to prevent offensive odors from entering patients' rooms and public halls. --Each patient room shall be an outside room and well ventilated. --The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A. --The latest edition of the NBFU-Bulletin 56 published by the National Board of Fire Underwriters, shall be adopted by reference.
	*State rule specifies that the latest edition of the "ASHRAE Guide published by ASHRAE" shall be adopted by reference.
NEVADA	2.3 2.4
Reference:	Nevada State Division of Health, Bureau of Health Facilities. General Hospital Construction Standards. Adopted Agust 26, 1969.
Standard:	1969 Hill-Burton Standard, adopted by rule (Plans to adopt "ASHRAE Standards").
Additional Requirements:	--None.

		Table
NEW HAMPSHIRE		2.2
Reference:	State of New Hampshire, Department of Health and Welfare, Division of Public Health Services, Bureau of Health Facilities Administration.	
Standard:	1974 Hill-Burton Standard, adopted by rule.	
Additional Requirements:	--None.	
NEW JERSEY		2.6.19
Reference:	New Jersey State Department of Health. Manual of Standards for Hospital Facilities. Amended January 1976.	
Standard:	1974 Hill-Burton Standard. Adopted by reference.	
Additional Requirements:	--None	
NEW MEXICO		2.6.20
Reference:	State of New Mexico, Department of Public Health, Health and Social Services Department, Licensing and Certification Section. Rules, Regulations and Standards for Hospitals and Sanatoria Infirmaries, Diagnostic and Treatment Centers and Rehabilitation Centers. Effective July 25, 1964, last amended August 20, 1965.	
Standard:	State.	
Additional Requirements:	--The 1974 Hill-Burton Standard (Table 2.2) is required when Hill-Burton funding is involved. --The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.	
NEW YORK		2.6.21
Reference:	State of New York, Department of Health, Office of Health Systems Management. Title X, New York Codes Rules and Regulations, Chapter V. Effective July 31, 1976	
Standard:	1974 Hill-Burton Standard, adopted by rule.	

Additional Requirements:
--The ventilation, heating, air conditioning, and air changing systems shall be maintained in a manner which will prevent the spread of infection and provide for patient or resident health and comfort.
--The ventilation, heating, air conditioning, and air changing systems shall be provided, as needed, with acceptable air filtration equipment that is cleaned and serviced at adequate intervals.
--It will be assured that the relative humidity is maintained at a minimum of 50% in those areas where conductive floors are required.
--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.

NORTH CAROLINA 2.6.20

Reference: State of North Carolina, Department of Human Resources, Division of Health Services. Laws, Regulations and the Procedures Applying to the Licensing of Hospitals in North Carolina. Adopted June 19, 1964.

Standard: State.

Additional Requirements:
--Each patient's room shall have at least one window, opening to the outside to permit ventilation and a source of light.
--Kitchens, morgues, bathrooms, and service rooms shall be so located and ventilated by window or mechanical devices to prevent offensive odors from entering patients' rooms and public halls.
--A mechanical air supply system shall be provided for year-round usage in operating and delivery rooms.
--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.

NORTH DAKOTA 2.6.21

Reference: North Dakota State Department of Health, Division of Health Facilities. Rules and Regulations for Hospitals in North Dakota. Adopted 1976.

Standard: State.

Additional Requirements:
--See specifications in Table 2.2.1, "Filter Efficiencies for Central Ventilation and Air Conditioning Systems in General Hospitals."

--The ventilation system for anesthesia storage rooms shall conforma to the requirements of NFPA Standard 56A-1973.
--The nursery premature unit shall have a temperature maintained between 75 and 80°F and relative humidity maintained between 50 and 60%.

OHIO 2.2

Reference: State of Ohio, Department of Health, Bureau of Medical Services. Ohio Building Code.

Standard: 1974 Hill-Burton Standard, adopted by reference.

Additional Requirements: --None.

OKLAHOMA 2.6.22

Reference: Oklahoma State Department of Health, Health Facilities Licensure. Standards and Regulations for Licensure of Hospitals and Related Institutions. amended March 11, 1978.

Standard: State.

Additional Requirements:
--Provisions shall be made for an adequate supply of fresh air from the outside, (whether heated, cooled or temperature unchanged) for all rooms and areas of the hospital.
--All patient rooms shall have, as a minimum, outside window area equal to 10% of the room floor area, with sufficient opening sashes to provide natural ventilation when necessary.
--Operating, delivery, nursery, and isolation rooms shall have an adequate supply of fresh air from the outside, preferably 100%.
--Rooms, and areas, other than those afore mentioned, shall have a minimum of 10% fresh air supply from their ventilating system.

OREGON 2.5

Reference: State of Oregon, Department of Human Resources Health Division, Health Facilities Licensing and Certification Section. Rules for Inpatient Care Facilities in Oregon. Adopted June 1, 1976.

Standard: NFPA Standard 101, adopted by reference.

Additional Requirements: --None.

	Table
PENNSYLVANIA	2.2
Reference:	Commonwealth of Pennsylvania, Department of Health, Division of Licensure. Rules and Regulations for Hospitals. Adopted April 1, 1966; last revised June 25, 1976.
Standard:	1976 Hill-Burton Standard, adopted by rule.
Additional Requirements:	--Patient rooms shall be provided with natural ventilation.
RHODE ISLAND	2.2
Reference:	State of Rhode Island, and Providence Plantations Department of Health, Medical Care Standards. Rules and Regulations for Licensing of Hospitals. Adopted August 1973; last amended May 1977.
Standard:	1974 Hill-Burton Standard, adopted by reference .
Additional Requirements:	--None.
SOUTH CAROLINA	2.5
Reference:	South Carolina Department of Health and Environmental Control, Bureau of Health Facilities Engineering. Minimum Standards for Licensing in South Carolina Hospitals and Institutional Infirmaries. Adopted May 1968.
Standard:	NFPA Standard 101, adopted by rule*.
Additional Requirements:	--The building must be equipped with a central heating system adequage to maintain a temperature range of 70-80 F. --There shall be an adequate supply and forced exhaust ventilation of utility rooms, kitchens, dishwashing area, laundry, toilets, baths, storerooms, work rooms, operating rooms, delivery rooms, X-ray rooms, emergency rooms, sterilizer equipment rooms, and maintenance shop. --All institutions shall be located so that they are free from undue noises, smoke, dust or foul odors.
	*Informally applies latest Hill-Burton Standard.

	Table
SOUTH DAKOTA	2.6.23
Reference:	South Dakota Department of Health, Office of State Health Planning and Development, Facility Development Section, Resource Development Program. Construction Standards.
Standard:	State.
Additional Requirements:	--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.
TENNESSEE	2.2
Reference:	State of Tennessee, Department of Public Health, Technical Services Program. Minimum Standards and Regulations for Hospitals. Revised 1974.
Standard:	None* (Plans to adopt 1974 Hill-Burton Standard).
Additional Requirements:	--The heating plant shall be of sufficient size to maintain a temperature of at least 70 F. --The hospital building shall be adequately ventilated at all times to reduce airborne contamination. --Bathrooms, utility and service rooms, shall be ventilated by forced mechanical means. --Medium efficiency filters are required throughout with high efficiency filters in critical areas. *Informally applies 1974 Hill-Burton Standard
TEXAS	2.6.24
Reference:	State of Texas, Department of Health, Hospital Licensing Division. Hospital Licensing Standards. Effective April 15, 1969.
Standard:	State.
Additional Requirements:	--The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A-1960.
UTAH	2.2
Reference:	State of Utah, Department of Social Services, Division of Health, Medical Care and Facilities Branch, Bureau of Medicaid Certification. Adopted 1968; last revised July 10, 1977.
Standard:	1974 Hill-Burton Standard, adopted by reference.
Additional Requirements:	--None.

	Table
VERMONT	2.5
Reference: State of Vermont, Agency of Human Services, Department of Health, Medical Care Facilities.	
Standard: NFPA Standard 101, adopted by reference*.	
Additional Requirements: --None.	
*Informally applies 1974 Hill-Burton Standard	
VIRGINIA	2.2
Reference: Commonwealth of Virginia, Department of Health, Bureau of Medical and Nursing Facilities Services. Rules and Regulations for the Licensure of General and Special Hospitals in Virginia. Adopted September 1, 1976; effective Janaury 1, 1977.	
Standard: 1974 Hill-Burton Standard, adopted by rule.	
Additional Requirements: --None.	
WASHINGTON	2.6.25
Reference: State of Washington, Department of Social and Health Services, Health Services Division, Office of Health Resources Development, Licensing and Development Section. Hospital Rules and Regulations. Amended January 1977.	
Standard: State.	
Additional Requirements: --Comfortable temperatures must be maintained throughout the hospital. --Adequate ventilation must be provided for all areas of the hospital. --All supply ventilation systems shall include properly designed, electronic or mechanical filters. --The ventilation system for anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A-1960.	
WEST VIRGINIA	2.2
Reference: State of West Virginia, Department of Health, Health Insurance Benefits Unit.	
Standard: 1974 Hill-Burton Standard, adopted by reference.	
Additional Requirements: --None.	

Table

WISCONSIN 2.6.26

Reference: State of Wisconsin, Department of Health and Social Services, Division of Health, Bureau of Quality Compliance, Facilities Need Analysis Secion. Wisconsin Administrative Code, Rules of the Division of Health, Chapter H-24, General and Special Hospitals. Effective June 1, 1968.

Standard: State (Plans to adopte 1974 Hill-Burton Standard).

Additional Requirements:
--Recirculation of air shall only be permitted within the system serving an individual room.
--The air movement in corridors and halls shall not be less than 10 CFM per lineal foot of corridor or hall.
--The ventilation system serving anesthesia storage rooms shall conform to the requirements of NFPA Standard 56A.

WYOMING 2.5

Reference: State of Wyoming, Department of Health and Social Services, Division of Health and Medical Services, Medical Services. Hospital Rules and Regulations. Draft.

Standard: NFPA Standard 101, adopted by reference.

Additional Requirements:
--The air supplied to the operating and delivery rooms shall be filtered to remove 90-99% of all particulates.
--The anesthesia storage room shall be continuously ventilated.
--The linen and trash chute rooms, the laundry, the soiled and clean linen rooms, shall be provided with adequate ventilation.
--Adequate temperatures must be maintained in the laundry.

PUERTO RICO . . .

Reference: Commonwealth of Puerto Rico, Department of Health Facilities.

Standard: 1974 Hill-Burton Standard, adopted by reference.

Additional Requirements: --None

TABLE 2.6.1: DEPARTMENT OF THE AIR FORCE

Area Designation	Relative Pressure	Outdoor Air CFM Per Square Feet	Total CFM Per Square Feet	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	-	3.5	-	50-60	70-75
Emergency Operating Room	P	-	3.5	-	50-60	70-75
Delivery Room	P	-	3.5	-	50-60	70-75
Nursery Suite	P	-	2	-	50	75
Recovery Room	-	-	-	-	-	-
Intensive Care	P	-	2	-	50-60	70-75
Patient Room	E	-	2	-	40-50	75
Patient Corridor	E	-	0.4	-	30-55	75
Isolation Room	N	-	3	No	30-55	75
Isolation Alcove	-	-	-	-	-	-
Examination Room	-	-	-	-	-	-
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	-	-	-	-	-	-
X-ray, Fluoroscopy Room	-	-	-	-	-	-
X-ray, Examination Room	-	-	-	-	-	-
Physical Therapy and Hydrotherapy	-	-	-	-	-	-
Soiled Utility	N	-	1.5	No	30-55	75
Clean Utility	P	-	0.8	-	30-55	75
Autopsy	N	-	2	No	30-55	75
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	N	-	1	No	30-55	75
Toilet Room	N	-	2.5	No	30-55	75
Bedpan Room	-	-	-	-	-	-
Bathroom	N	-	2.5	No	30-55	75
Janitors' Closet	N	-	1	No	30-55	75
Sterilizer Equipment Room	-	-	-	-	-	-
Linen and Trash Chute Rooms	-	-	-	-	-	-
Laboratory, General	N	-	1.5	No	30-55	75
Laboratory, Media Transfer	P	-	2	-	30-55	75
Food Preparation Centers	N	-	4.5	No	30-55	75
Warewashing	-	-	-	-	-	-
Dietary Day Storage	-	-	-	-	-	-
Laundry, General	-	-	-	-	-	-
Soiled Linen	-	-	-	-	-	-
Clean Linen	-	-	-	-	-	-
Anesthesia Storage	E	-	8	No	30-55	75
Central Medical and Surgical Supply:						
Soiled Room	-	-	-	-	-	-
Clean Workroom	-	-	-	-	-	-
Unsterile Supply Storage	-	-	-	-	-	-

TABLE 2.6.2: DEPARTMENT OF THE ARMY

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recircu-lation	Percent Humidity	Temperature (°F)
Operating Room	P	5	25	No	55	68-76
Emergency Operating Room	P	5	25	No	55	68-76
Delivery Room	P	5	25	No	55	70-76
Nursery Suite	P	3	12	No	55	75
Recovery Room	P	5	12	No	55	75
Intensive Care	P	5	12	No	55	70-80
Patient Room	E	2	6	No	35-55	75
Patient Corridor	E	2	6	Optional	-	70-78
Isolation Room	N	5	12	No	-	70-78
Isolation Alcove	N	5	12	No	-	70-78
Examination Room	E	2	6	No	-	70-78
Medication Room	-	-	-	-	-	70-78
Pharmacy	P	2	4	Optional	-	70-78
Treatment Room	E	2	6	No	-	70-78
X-ray, Fluoroscopy Room	N	2	6	No	-	70-78
X-ray, Treatment Room	E	2	6	Optional	-	70-78
Physical Therapy and Hydro-therapy	N	2	6	Optional	-	70-78
Soiled Utility	N	2	4	No	-	70-78
Clean Utility	P	2	4	Optional	-	70-78
Autopsy	N	3	15	No	-	70-78
Workroom	-	-	-	-	-	70-78
Warefrigerated Body Holding Room	-	-	-	-	-	70-78
Toilet Room	-	-	-	-	-	70-78
Bedpan Room	-	-	-	-	-	70-78
Bathroom	N	Optional	10	No	-	70-78
Janitors' Closet	N	Optional	10	No	-	70-78
Sterilizer Equipment Room	E	2	10	No	-	70-78
Linen and Trash Chute Rooms	N	Optional	10	No	-	70-78
Laboratory, General	N	2	6	No	-	70-78
Laboratory, Media Transfer	N	2	6	No	-	70-78
Food Preparation Centers	N	2	10	No	-	70-78
Warewashing	N	Optional	10	No	-	70-78
Dietary Day Storage	E	Optional	4	No	-	70-78
Laundry, General	-	-	-	-	-	70-78
Soiled Linen	N	4	12	No	-	70-78
Clean Linen	P	2	4	Optional	-	70-78
Anesthesia Storage	E	2	4	No	-	70-78
Central Medical and Surgical Supply						
Soiled Room	N	2	8	No	-	70-78
Clean Workroom	P	2	6	Optional	-	70-78
Unsterile Supply Storage	E	2	4	Optional	-	70-78

TABLE 2.6.3: DEPARTMENT OF THE NAVY

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	25	No	50-60	68-80
Emergency Operating Room	P	5	25	No	50-60	68-80
Delivery Room	P	5	25	No	50-60	68-76
Nursery Suite	P	5	12	Optional	50	75
Recovery Room	P	3	12	Optional	50	75
Intensive Care	P	2	6	Optional	50	75
Patient Room	E	2	4	Optional	50	75
Patient Corridor	-	-	-	-	-	-
Isolation Room	E	1.5	6	No	50	75
Isolation Alcove	P	2.5	10	No	50	75
Examination Room	E	1.5	6	Optional	50	75
Medication Room	P	1	4	Optional	50	75
Pharmacy	-	-	-	-	-	-
Treatment Room	E	1.5	6	Optional	50	75
X-ray, Fluoroscopy Room	N	1.5	6	Optional	50	78
X-ray, Treatment Room	E	1.5	6	Optional	50	78
Physical Therapy and Hydrotherapy	E	1.5	6	Optional	50	75-80
Soiled Utility	N	2.5	10	Optional	50	75
Clean Utility	P	1.5	6	Optional	50	75
Autopsy	N	3	12	No	50	75
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	N	Optional	10	No	50	75
Bedpan Room	-	-	-	-	-	-
Bathroom	-	-	-	-	-	-
Janitors' Closet	N	Optional	10	No	-	-
Sterilizer Equipment Room	-	-	-	-	-	-
Linen and Trash Chute Rooms	-	-	-	-	-	-
Laboratory, General	-	-	-	-	-	-
Laboratory, Media Transfer	-	-	-	-	-	-
Food Preparation Centers	-	-	-	-	-	-
Warewashing	-	-	-	-	-	-
Dietary Day Storage	-	-	-	-	-	-
Laundry, General	-	-	-	-	-	-
Soiled Linen	-	-	-	-	-	-
Clean Linen	-	-	-	-	-	-
Anesthesia Storage	-	-	-	-	-	-
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	-
Clean Workroom	-	-	-	-	-	-
Unsterile Supply Storage	-	-	-	-	-	-

TABLE 2.6.4: INDIAN HEALTH SERVICE

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	25	No	50-60	70-76
Emergency Operating Room	P	5	25	No	50-60	70-76
Delivery Room	P	5	12	No	50-60	70-76
Nursery Suite	P	5	15	No	30-60	75
Recovery Room	P	2	6	No	50-60	72-78
Intensive Care	P	2	6	No	30-60	72-78
Patient Room	V	2	2	Optional	-	72-78
Patient Corridor	V	2	2	Optional	-	72-78
Isolation Room	P/N	2	6	No	-	72-78
Isolation Alcove	P/N	2	6	No	-	72-78
Examination Room	V	2	6	Optional	-	72-78
Medication Room	V	2	2	Optional	-	72-78
Pharmacy	V	2	2	Optional	-	72-78
Treatment Room	V	2	6	Optional	-	72-78
X-ray, Fluoroscopy Room	V	2	6	No	-	72-78
X-ray, Treatment Room	V	2	6	No	-	72-78
Physical Therapy and Hydrotherapy	N	2	6	Optional	-	72-78
Soiled Utility	N	2	10	No	-	72-78
Clean Utility	P	2	4	Optional	-	72-78
Autopsy	N	2	12	No	-	72-78
Workroom	-	-	-	-	-	72-78
Warefrigerated Body Holding Room	N	2	10	No	-	72-78
Toilet Room	N	Optional	10	No	-	72-78
Bedpan Room	-	-	-	-	-	72-78
Bathroom	N	Optional	10	No	-	72-78
Janitors' Closet	N	2	10	No	-	72-78
Sterilizer Equipment Room	-	-	-	-	-	72-78
Linen and Trash Chute Rooms	-	-	-	-	-	72-78
Laboratory, General	N	2	6	Optional	-	72-78
Laboratory, Media Transfer	P	2	6	No	-	72-78
Food Preparation Centers	N	2	10	No	-	72-78
Warewashing	N	Optional	10	No	-	72-78
Dietary Day Storage	V	2	2	No	-	72-78
Laundry, General	N	2	10	No	-	72-78
Soiled Linen	N	2	10	No	-	72-78
Clean Linen	P	2	4	Optional	-	72-78
Anesthesia Storage	E	-	8	No	-	72-78
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	72-78
Clean Workroom	-	-	-	-	-	72-78
Unsterile Supply Storage	V	2	2	No	-	72-78

TABLE 2.6.5: VETERAN'S ADMINISTRATION

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	15	15	No	50	70
Emergency Operating Room	P	15	15	No	50	70
Delivery Room	-	-	-	-	30-50	72-78
Nursery Suite	-	-	-	-	30-50	72-78
Recovery Room	P	15	15	No	50	70
Intensive Care	P	-	-	-	30-50	72-78
Patient Room	-	-	-	-	30-50	72-78
Patient Corridor	-	-	-	-	30-50	72-78
Isolation Room	P/N	-	-	No	30-50	72-78
Isolation Alcove	P/N	-	-	No	30-50	72-78
Examination Room	-	-	-	-	30-50	72-78
Medication Room	-	-	-	-	30-50	72-78
Pharmacy	-	-	-	-	30-50	72-78
Treatment Room	-	-	-	-	30-50	72-78
X-ray, Fluoroscopy Room	-	-	-	-	30-50	72-78
X-ray, Treatment Room	-	-	-	No	30-50	72-78
Physical Therapy and Hydrotherapy	-	-	-	-	30-50	72-78
Soiled Utility	N	-	-	No	30-50	72-78
Clean Utility	-	-	-	-	30-50	72-78
Autopsy	N	15	15	No	30-50	72-78
Workroom	-	-	-	-	30-50	72-78
Warefrigerated Body Holding koom	-	-	-	-	30-50	72-78
Toilet Room	N	10	10	No	30-50	72-78
Bedpan Room	-	-	-	-	30-50	72-78
Bathroom	-	10	10	No	30-50	72-78
Janitors' Closet	-	-	-	-	30-50	72-78
Sterilizer Equipment Room	-	-	-	-	30-50	72-78
Linen and Trash Chute Rooms	-	-	-	No	30-50	72-78
Laboratory, General	-	-	-	No	30-50	72-78
Laboratory, Media Transfer	-	-	-	-	30-50	72-78
Food Preparation Centers	-	-	-	No	30-50	72-78
Warewashing	-	-	-	No	30-50	72-78
Dietary Day Storage	-	-	-	-	30-50	72-78
Laundry, General	-	-	-	-	30-50	72-78
Soiled Linen	-	-	-	-	30-50	72-78
Clean Linen	-	-	-	-	30-50	72-78
Anesthesia Storage	-	-	-	No	30-50	72-78
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	30-50	72-78
Clean Workroom	-	-	-	-	30-50	72-78
Unsterile Supply Storage	-	-	-	-	30-50	72-78

TABLE 2.6.6: STATE OF ALABAMA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	-	-	-	-	-	70-75
Emergency Operating Room	-	-	-	-	-	70-75
Delivery Room	-	-	-	-	-	70-75
Nursery Suite	-	-	-	No	-	70-75
Recovery Room	-	-	-	-	-	70-75
Intensive Care	-	-	-	-	-	70-75
Patient Room	-	-	-	-	-	70-75
Patient Corridor	-	-	-	-	-	70-75
Isolation Room	-	-	-	-	-	70-75
Isolation Alcove	-	-	-	-	-	70-75
Examination Room	-	-	-	-	-	70-75
Medication Room	-	-	-	-	-	70-75
Pharmacy	-	-	-	-	-	70-75
Treatment Room	-	-	-	-	-	70-75
X-ray, Fluoroscopy Room	-	-	-	-	-	70-75
X-ray, Treatment Room	-	-	-	-	-	70-75
Physical Therapy and Hydrotherapy	-	-	-	-	-	70-75
Soiled Utility	-	-	-	-	-	70-75
Clean Utility	-	-	-	-	-	70-75
Autopsy	-	-	-	-	-	70-75
Workroom	-	-	-	-	-	70-75
Warefrigerated Body Holding Room	-	-	-	-	-	70-75
Toilet Room	-	-	-	-	-	70-75
Bedpan Room	-	-	-	-	-	70-75
Bathroom	-	-	-	-	-	70-75
Janitors' Closet	-	-	-	-	-	70-75
Sterilizer Equipment Room	-	-	-	-	-	70-75
Linen and Trash Chute Rooms	-	-	-	-	-	70-75
Laboratory, General	-	-	-	-	-	70-75
Laboratory, Media Transfer	-	-	-	-	-	70-75
Food Preparation Centers	-	-	-	-	-	70-75
Warewashing	-	-	-	-	-	70-75
Dietary Day Storage	-	-	-	-	-	70-75
Laundry, General	-	-	-	No	-	70-75
Soiled Linen	-	-	-	-	-	70-75
Clean Linen	-	-	-	-	-	70-75
Anesthesia Storage	E	-	8	No	-	70-75
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	70-75
Clean Workroom	-	-	-	-	-	70-75
Unsterile Supply Storage	-	-	-	-	-	70-75

TABLE 2.6.7: STATE OF ARKANSAS

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recircu-lation	Percent Humidity	Temperature (°F)
Operating Room	P	12	12	No	50-60	65-70
Emergency Operating Room	P	12	12	No	50-60	65-70
Delivery Room	P	12	12	No	50-60	70-76
Nursery Suite	P	12	12	No	50	75
Recovery Room	E	6	6	Optional	50-60	75
Intensive Care	P	6	6	No	30-60	70-80
Patient Room	E	2	2	Optional	-	75
Patient Corridor	E	4	4	Optional	-	75
Isolation Room	E	6	6	No	-	75
Isolation Alcove	E	6	6	No	-	75
Examination Room	-	-	-	-	-	-
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	E	6	6	No	-	75
X-ray, Fluoroscopy Room	N	6	6	No	-	75
X-ray, Treatment Room	N	6	6	No	-	75
Physical Therapy and Hydro-therapy	N	6	6	Optional	-	75
Soiled Utility	N	4	4	No	-	75
Clean Utility	P	4	4	Optional	-	75
Autopsy	N	6	15	No	-	75
Workroom	N	6	15	No	-	75
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	N	Optional	10	No	-	75
Bedpan Room	N	Optional	10	No	-	75
Bathroom	N	Optional	10	No	-	75
Janitors' Closet	N	Optional	10	No	-	75
Sterilizer Equipment Room	N	Optional	10	No	-	75
Linen and Trash Chute Rooms	N	Optional	10	No	-	75
Laboratory, General	N	6	6	Optional	-	75
Laboratory, Media Transfer	P	4	4	No	-	75
Food Preparation Centers	E	10	10	No	-	75
Warewashing	N	Optional	10	No	-	75
Dietary Day Storage	E	Optional	2	No	-	75
Laundry, General	E	10	10	No	-	75
Soiled Linen	N	Optional	10	No	-	75
Clean Linen	P	2	2	Optional	-	75
Anesthesia Storage	E	8	8	No	-	75
Central Medical and Surgical Supply						
Soiled Room	N	4	4	No	-	75
Clean Workroom	P	4	4	No	-	75
Unsterile Supply Storage	E	2	2	Optional	-	75

TABLE 2.6.8: STATE OF CALIFORNIA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	12	12	No	50-60	70-76
Emergency Operating Room	P	12	12	No	50-60	72-75
Delivery Room	P	12	12	No	50-60	70-76
Nursery Suite	P	8	8	No	30-60	70-76
Recovery Room	E	6	6	No	50-60	70-76
Intensive Care	P	6	6	No	30-60	70-80
Patient Room	E	2	2	Optional	-	72-75
Patient Corridor	E	2	2	Optional	-	72-75
Isolation Room	E	6	6	No	-	72-75
Isolation Alcove	E	6	6	No	-	72-75
Examination Room	E	6	6	No	-	72-75
Medication Room	-	-	-	-	-	72-75
Pharmacy	-	-	-	-	-	72-75
Treatment Room	E	6	6	No	-	72-75
X-ray, Fluoroscopy Room	N	6	6	No	-	72-75
X-ray, Treatment Room	E	6	6	Optional	-	72-75
Physical Therapy and Hydrotherapy	N	6	6	Optional	-	72-75
Soiled Utility	N	4	4	No	-	72-75
Clean Utility	P	4	4	Optional	-	72-75
Autopsy	N	8	8	No	-	72-75
Workroom	N	8	8	No	-	72-75
Warefrigerated Body Holding Room	-	-	-	-	-	72-75
Toilet Room	N	Optional	10	No	-	72-75
Bedpan Room	N	Optional	10	No	-	72-75
Bathroom	N	Optional	10	No	-	72-75
Janitors' Closet	N	Optional	10	No	-	72-75
Sterilizer Equipment Room	N	Optional	10	No	-	72-75
Linen and Trash Chute Rooms	N	Optional	10	No	-	72-75
Laboratory, General	N	6	6	Optional	-	72-75
Laboratory, Media Transfer	P	4	4	No	-	72-75
Food Preparation Centers	E	10	10	No	-	72-75
Warewashing	N	Optional	10	No	-	72-75
Dietary Day Storage	E	Optional	2	Optional	-	72-75
Laundry, General	E	10	10	No	-	72-75
Soiled Linen	N	-	-	No	-	72-75
Clean Linen	P	2	2	Optional	-	72-75
Anesthesia Storage	E	8	8	No	-	72-75
Central Medical and Surgical Supply						
Soiled Room	N	4	4	No	-	72-75
Clean Workroom	P	4	4	Optional	-	72-75
Unsterile Supply Storage	E	2	2	Optional	-	72-75

TABLE 2.6.9: STATE OF CALIFORNIA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recircu-lation	Percent Humidity	Temperature (°F)
Operating Room	P	5	25	No	50-60	70-76
Emergency Operating Room	P	5	25	No	50-60	72-75
Delivery Room	P	5	20	No	50-60	70-76
Nursery Suite	P	3	12	No	30-60	70-76
Recovery Room	E	2	6	No	50-60	70-76
Intensive Care	P	2	6	No	30-60	70-80
Patient Room	E	2	2	Optional	-	72-75
Patient Corridor	E	2	4	Optional	-	72-75
Isolation Room	E	2	6	No	-	72-75
Isolation Alcove	E	2	6	No	-	72-75
Examination Room	E	2	6	No	-	72-75
Medication Room	-	-	-	-	-	72-75
Pharmacy	-	-	-	-	-	72-75
Treatment Room	E	2	6	No	-	72-75
X-ray, Fluoroscopy Room	N	2	6	No	-	72-75
X-ray, Treatment Room	E	2	6	Optional	-	72-75
Physical Therapy and Hydro-therapy	N	2	6	Optional	-	72-75
Soiled Utility	N	2	10	No	-	72-75
Clean Utility	P	2	6	Optional	-	72-75
Autopsy	N	2	12	No	-	72-75
Workroom	N	2	12	No	-	72-75
Warefrigerated Body Holding Room	-	-	-	-	-	72-75
Toilet Room	N	Optional	10	No	-	72-75
Bedpan Room	N	Optional	10	No	-	72-75
Bathroom	N	Optional	10	No	-	72-75
Janitors' Closet	N	Optional	10	No	-	72-75
Sterilizer Equipment Room	N	Optional	10	No	-	72-75
Linen and Trash Chute Rooms	N	Optional	10	No	-	72-75
Laboratory, General	N	2	6	Optional	-	72-75
Laboratory, Media Transfer	P	2	4	No	-	72-75
Food Preparation Centers	E	2	10	No	-	72-75
Warewashing	N	Optional	10	No	-	72-75
Dietary Day Storage	E	Optional	2	Optional	-	72-75
Laundry, General	E	2	10	No	-	72-75
Soiled Linen	N	Optional	10	No	-	72-75
Clean Linen	P	2	2	Optional	-	72-75
Anesthesia Storage	E	-	8	No	-	72-75
Central Medical and Surgical Supply						
Soiled Room	N	2	4	No	-	72-75
Clean Workroom	P	2	4	Optional	-	72-75
Unsterile Supply Storage	E	2	2	Optional	-	72-75

TABLE 2.6.10: STATE OF CONNECTICUT

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	25	No (1)	50-60	68-78
Emergency Operating Room	P	5	25	No (1)	50-60	68-78
Delivery Room	P	5	12	No (1)	50-60	68-78
Nursery Suite	P	5	12	No (1)	30-60	72-78
Recovery Room	P	2	6	No (1)	40-60	72-78
Intensive Care	P	2	6	No (1)	30-60	72-80
Patient Room	E	2	2	Optional	-	75
Patient Corridor	E	2	4	Optional	-	75
Isolation Room	E	2	6	No	-	75
Isolation Alcove	E	2	10	No	-	75
Examination Room	E	2	6	Optional	-	75
Medication Room	P	2	4	Optional	-	75
Pharmacy	P	2	4	Optional	-	75
Treatment Room	E	2	6	No (1)	-	75
X-ray, Fluoroscopy Room	N	2	6	No	-	75
X-ray, Treatment Room	E	2	6	Optional	-	75
Physical Therapy and Hydrotherapy	N	2	6	Optional	-	75
Soiled Utility	N	2	10	No	-	75
Clean Utility	P	2	4	Optional	-	75
Autopsy	N	2	12	No	-	75
Workroom	N	2	10	No	-	75
Warefrigerated Body Holding Room	N	Optional	10	No	-	75
Toilet Room	N	Optional	10	No	-	75
Bedpan Room	N	Optional	10	No	-	75
Bathroom	N	Optional	10	No	-	75
Janitors' Closet	N	Optional	10	No	-	75
Sterilizer Equipment Room	N	Optional	10	No	-	75
Linen and Trash Chute Rooms	N	Optional	10	No	-	75
Laboratory, General	N	2	6	Optional	-	75
Laboratory, Media Transfer	P	2	4	No (1)	-	75
Food Preparation Centers	E	2	10	No	-	75
Warewashing	N	Optional	10	No	-	75
Dietary Day Storage	E	Optional	2	Optional	-	75
Laundry, General	E	2	10	No	-	75
Soiled Linen	N	Optional	10	No	-	75
Clean Linen	P	2	2	Optional	-	75
Anesthesia Storage	E	Optional	8	No	-	75
Central Medical and Surgical Supply						
Soiled Room	N	2	6	No	-	75
Clean Workroom	P	2	4	Optional	-	75
Unsterile Supply Storage	E	2	2	Optional	-	75

TABLE 2.6.11: STATE OF FLORIDA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	22	22	No	50-60	70-76
Emergency Operating Room	P	22	22	No	50-60	70-76
Delivery Room	P	22	22	No	50-60	70-76
Nursery Suite	P	5	15	No (6)	50	75
Recovery Room	E	6	15	No (3)	50-60	75
Intensive Care	P	6	6	No	30-60	70-80
Patient Room	E	2	4	No (4)	-	75
Patient Corridor	E	4	4	No (4)	-	75
Isolation Room	E	12	12	No	-	75
Isolation Alcove	N	12	12	No	-	75
Examination Room	E	6	6	No (4)	-	75
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	E	6	6	No (4)	-	75
X-ray, Fluoroscopy Room	N	6	6	No	-	75
X-ray, Treatment Room	N	6	6	No	-	75
Physical Therapy and Hydrotherapy	N	4	4	No (4)	-	75
Soiled Utility	N	4	12	No (4)	-	75
Clean Utility	P	4	12	No (4)	-	75
Autopsy	N	6	15	No	-	75
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	N	Optional	10	No	-	75
Bedpan Room	N	Optional	10	No	-	75
Bathroom	N	Optional	10	No	-	75
Janitors' Closet	N	Optional	10	No	-	75
Sterilizer Equipment Room	N	Optional	10	No	-	75
Linen and Trash Chute Rooms	N	Optional	10	No	-	75
Laboratory, General	N	6	6	No	-	75
Laboratory, Media Transfer	P	4	4	No	-	75
Food Preparation Centers	E	20	20	No	-	75
Warewashing	N	Optional	10	No	-	75
Dietary Day Storage	E	2	2	No (5)	-	75
Laundry, General	E	10	10	No	-	75
Soiled Linen	N	Optional	10	No	-	75
Clean Linen	P	2	2	No (4)	-	75
Anesthesia Storage	E	8	8	No	-	75
Central Medical and Surgical Supply						
Soiled Room	N	4	12	No	-	75
Clean Workroom	P	2	2	No (4)	-	75
Unsterile Supply Storage	-	-	-	-	-	-

TABLE 2.6.12: STATE OF FLORIDA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	22	No (7)	50-60	70-76
Emergency Operating Room	P	5	22	No (7)	50-60	70-76
Delivery Room	P	5	22	No (7)	50-60	70-76
Nursery Suite	P	2.8	15	No (7)	50	75
Recovery Room	E	2.8	15	No (6)	50-60	75
Intensive Care	P	2.8	6	No (6)	30-60	70-80
Patient Room	E	1.1	4	No (3)	-	75
Patient Corridor	E	2	4	No (3)	-	75
Isolation Room	E	4	12	No	-	75
Isolation Alcove	N	4	12	No	-	75
Examination Room	E	2.8	6	No (3)	-	75
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	E	2.8	6	No (3)	-	75
X-ray, Fluoroscopy Room	-	-	-	-	-	-
X-ray, Treatment Room	-	-	-	-	-	-
Physical Therapy and Hydrotherapy	N	2.25	4	No (3)	-	75
Soiled Utility	N	2.25	12	No (3)	-	75
Clean Utility	P	2.25	12	No (3)	-	75
Autopsy	N	Optional	15	No	-	75
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	N	Optional	10	No	-	75
Bedpan Room	N	Optional	10	No	-	75
Bathroom	N	Optional	10	No	-	75
Janitors' Closet	N	Optional	10	No	-	75
Sterilizer Equipment Room	N	Optional	10	No	-	75
Linen and Trash Chute Rooms	N	Optional	10	No	-	75
Laboratory, General	N	2.25	6	No	-	75
Laboratory, Media Transfer	P	1.3	4	No	-	75
Food Preparation Centers	E	7	20	No (4)	-	75
Warewashing	N	Optional	10	No	-	75
Dietary Day Storage	E	1	2	No (4)	-	75
Laundry, General	E	3.3	10	No	-	75
Soiled Linen	N	Optional	10	No	-	75
Clean Linen	P	1	2	No (8)	-	75
Anesthesia Storage	E	2.8	8	No	-	75
Central Medical and Surgical Supply						
Soiled Room	N	Optional	12	No	-	75
Clean Workroom	P	1.1	2	No (3)	-	75
Unsterile Supply Storage	-	-	-	-	-	-

TABLE 2.6.13: STATE OF IDAHO

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recircu-lation	Percent Humidity	Temperature (°F)
Operating Room	-	-	8	No	-	75
Emergency Operating Room	-	-	-	-	-	75
Delivery Room	-	-	8	No	-	75
Nursery Suite	-	-	-	-	-	75
Recovery Room	-	-	-	-	-	70
Intensive Care	-	-	-	-	-	70
Patient Room	-	-	-	-	-	70
Patient Corridor	-	-	-	-	-	70
Isolation Room	-	-	-	-	-	70
Isolation Alcove	-	-	-	-	-	70
Examination Room	-	-	-	-	-	70
Medication Room	-	-	-	-	-	70
Pharmacy	-	-	-	-	-	70
Treatment Room	-	-	-	-	-	70
X-ray, Fluoroscopy Room	-	-	-	-	-	70
X-ray, Treatment Room	-	-	-	-	-	70
Physical Therapy and Hydro-therapy	-	-	-	-	-	70
Soiled Utility	-	-	10	-	-	70
Clean Utility	-	-	10	-	-	70
Autopsy	-	-	10	No	-	70
Workroom	-	-	-	-	-	70
Warefrigerated Body Holding Room	-	-	-	-	-	70
Toilet Room	-	-	10	-	-	70
Bedpan Room	-	-	10	-	-	70
Bathroom	-	-	10	-	-	70
Janitors' Closet	-	-	-	-	-	70
Sterilizer Equipment Room	-	-	10	-	-	70
Linen and Trash Chute Rooms	-	-	-	No	-	70
Laboratory, General	-	-	-	-	-	70
Laboratory, Media Transfer	-	-	-	-	-	70
Food Preparation Centers	-	-	10	No	-	70
Warewashing	-	-	10	No	-	70
Dietary Day Storage	-	-	10	-	-	70
Laundry, General	-	-	10	No	-	70
Soiled Linen	-	-	-	No	-	70
Clean Linen	-	-	-	-	-	70
Anesthesia Storage	E	-	8	No	-	70
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	70
Clean Workroom	-	-	-	-	-	70
Unsterile Supply Storage	-	-	-	-	-	70

TABLE 2.6.14: STATE OF INDIANA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	20	No	45-60	65-75
Emergency Operating Room	P	5	20	No	45-60	65-75
Delivery Room	P	2	12	No	45-60	65-75
Nursery Suite	P	5	12	No	-	70
Recovery Room	P	2	6	No	50-60	70-75
Intensive Care	P	2	6	No (2)	30-60	70-75
Patient Room	E	2	2	Optional	-	70
Patient Corridor	E	2	4	Optional	-	70
Isolation Room	E	2	6	No	-	70
Isolation Alcove	E	2	10	No	-	70
Examination Room	E	2	6	Optional	-	70
Medication Room	P	2	4	Optional	-	70
Pharmacy	P	2	4	Optional	-	70
Treatment Room	E	2	6	No	-	70
X-ray, Fluoroscopy Room	N	2	6	No	-	70
X-ray, Treatment Room	E	2	6	Optional	-	70
Physical Therapy and Hydrotherapy	N	2	6	Optional	-	70
Soiled Utility	N	2	10	No	-	70
Clean Utility	P	2	4	Optional	-	70
Autopsy	N	2	12	No	-	70
Workroom	-	-	-	-	-	70
Warefrigerated Body Holding Room	N	Optional	10	No	-	70
Toilet Room	N	Optional	10	No	-	70
Bedpan Room	-	-	-	-	-	70
Bathroom	N	Optional	10	No	-	70
Janitors' Closet	N	Optional	10	No	-	70
Sterilizer Equipment Room	N	Optional	10	No	-	70
Linen and Trash Chute Rooms	N	Optional	10	No	-	70
Laboratory, General	N	2	6	Optional	-	70
Laboratory, Media Transfer	P	2	4	No	-	70
Food Preparation Centers	E	2	10	No	-	70
Warewashing	N	Optional	10	No	-	70
Dietary Day Storage	E	Optional	2	No	-	70
Laundry, General	E	2	10	No	-	70
Soiled Linen	N	Optional	10	No	-	70
Clean Linen	P	2	2	Optional	-	70
Anesthesia Storage	E	Optional	8	No	-	70
Central Medical and Surgical Supply						
Soiled Room	N	2	6	No	-	70
Clean Workroom	P	2	4	Optional	-	70
Unsterile Supply Storage	E	2	2	Optional	-	70

TABLE 2.6.15: STATE OF KENTUCKY

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	12	No	50-60	70-76
Emergency Operating Room	P	5	12	No	50-60	70-76
Delivery Room	P	5	12	No	50-60	70-76
Nursery Suite	P	5	12	No	50	75
Recovery Room	E	2	6	No	50-60	75
Intensive Care	P	2	6	No	30-60	75-80
Patient Room	E	2	2	Optional	-	72
Patient Corridor	E	2	4	Optional	-	72
Isolation Room	E	2	6	No	-	72
Isolation Alcove	E	2	6	No	-	72
Examination Room	-	-	-	-	-	72
Medication Room	-	-	-	-	-	72
Pharmacy	-	-	-	-	-	72
Treatment Room	E	2	6	No	-	72
X-ray, Fluoroscopy Room	N	2	6	No	-	72
X-ray, Treatment Room	E	2	6	Optional	-	72
Physical Therapy and Hydrotherapy	N	2	6	Optional	-	72
Soiled Utility	N	2	4	No	-	72
Clean Utility	P	2	4	Optional	-	72
Autopsy	N	2	12	No	-	72
Workroom	-	-	-	-	-	72
Warefrigerated Body Holding Room	-	-	-	-	-	72
Toilet Room	N	Optional	10	No	-	72
Bedpan Room	N	Optional	10	No	-	72
Bathroom	N	Optional	10	No	-	72
Janitors' Closet	N	Optional	10	No	-	72
Sterilizer Equipment Room	N	Optional	10	No	-	72
Linen and Trash Chute Rooms	N	Optional	10	No	-	72
Laboratory, General	N	2	6	Optional	-	72
Laboratory, Media Transfer	P	2	4	No	-	72
Food Preparation Centers	E	2	10	No	-	72
Warewashing	N	Optional	10	No	-	72
Dietary Day Storage	E	Optional	2	No	-	72
Laundry, General	E	2	10	No	-	72
Soiled Linen	N	Optional	10	No	-	72
Clean Linen	P	2	2	Optional	-	72
Anesthesia Storage	E	Optional	8	No	-	72
Central Medical and Surgical Supply						
Soiled Room	N	2	4	No	-	72
Clean Workroom	P	2	4	Optional	-	72
Unsterile Supply Storage	E	2	2	Optional	-	72

TABLE 2.6.16: STATE OF MINNESOTA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	-	-	8	No	55	75
Emergency Operating Room	-	-	8	No	55	75
Delivery Room	-	-	8	No	55	75
Nursery Suite	-	-	-	-	-	75
Recovery Room	-	-	-	-	-	75
Intensive Care	-	-	-	-	-	70
Patient Room	-	-	-	-	-	70
Patient Corridor	-	-	-	-	-	70
Isolation Room	-	-	-	-	-	70
Isolation Alcove	-	-	-	-	-	70
Examination Room	-	-	-	-	-	70
Medication Room	-	-	-	-	-	70
Pharmacy	-	-	-	-	-	70
Treatment Room	-	-	-	-	-	70
X-ray, Fluoroscopy Room	-	-	-	-	-	70
X-ray, Treatment Room	-	-	-	-	-	70
Physical Therapy and Hydrotherapy	-	-	10	-	-	70
Soiled Utility	-	-	10	-	-	70
Clean Utility	-	-	10	-	-	70
Autopsy	-	-	6	No	-	70
Workroom	-	-	-	-	-	70
Warefrigerated Body Holding Room	-	-	-	-	-	70
Toilet Room	-	-	10	-	-	70
Bedpan Room	-	-	10	-	-	70
Bathroom	-	-	10	-	-	70
Janitors' Closet	-	-	10	-	-	70
Sterilizer Equipment Room	-	-	10	-	-	70
Linen and Trash Chute Rooms	-	-	6	No	-	70
Laboratory, General	-	-	-	-	-	70
Laboratory, Media Transfer	-	-	-	-	-	70
Food Preparation Centers	-	-	6	No	-	70
Warewashing	-	-	6	No	-	70
Dietary Day Storage	-	-	6	No	-	70
Laundry, General	-	-	6	No	-	70
Soiled Linen	-	-	6	No	-	70
Clean Linen	-	-	6		-	70
Anesthesia Storage	-	-	-	-	-	70
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	70
Clean Workroom	-	-	-	-	-	70
Unsterile Supply Storage	-	-	-	-	-	70

TABLE 2.6.17: STATE OF MISSISSIPPI

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	-	-	-	-	50-60	70-76
Emergency Operating Room	-	-	-	-	50-60	70-76
Delivery Room	-	-	-	-	-	-
Nursery Suite	-	-	-	-	50	75-80
Recovery Room	-	-	-	-	-	-
Intensive Care	-	-	-	-	-	-
Patient Room	-	-	2	-	-	-
Patient Corridor	-	-	2	-	-	-
Isolation Room	-	-	-	-	-	-
Isolation Alcove	-	-	-	-	-	-
Examination Room	-	-	-	-	-	-
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	-	-	-	-	-	-
X-ray, Fluoroscopy Room	-	-	-	-	-	-
X-ray, Treatment Room	-	-	-	-	-	-
Physical Therapy and Hydrotherapy	-	-	-	-	-	-
Soiled Utility	-	-	-	-	-	-
Clean Utility	-	-	-	-	-	-
Autopsy	-	-	-	-	-	-
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	-	-	6	-	-	-
Bedpan Room	-	-	-	-	-	-
Bathroom	-	-	-	-	-	-
Janitors' Closet	-	-	6	-	-	-
Sterilizer Equipment Room	-	-	-	-	-	-
Linen and Trash Chute Rooms	-	-	-	-	-	-
Laboratory, General	-	-	-	-	-	-
Laboratory, Media Transfer	-	-	-	-	-	-
Food Preparation Centers	-	-	-	-	-	-
Warewashing	-	-	6	-	-	-
Dietary Day Storage	-	-	-	-	-	-
Laundry, General	-	-	-	-	-	-
Soiled Linen	-	-	6	-	-	-
Clean Linen	-	-	-	-	-	-
Anesthesia Storage	-	-	-	-	-	-
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	-
Clean Workroom	-	-	-	-	-	-
Unsterile Supply Storage	-	-	-	-	-	-

TABLE 2.6.18: STATE OF MISSOURI

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recircu-lation	Percent Humidity	Temperature (°F)
Operating Room	-	-	8	No	50-60	75
Emergency Operating Room	-	-	8	No	50-60	75
Delivery Room	-	-	8	No	50-60	75
Nursery Suite	-	-	-	-	-	75
Recovery Room	-	-	-	-	-	-
Intensive Care	-	-	-	-	-	-
Patient Room	-	-	-	-	-	-
Patient Corridor	-	-	-	-	-	-
Isolation Room	-	-	-	-	-	-
Isolation Alcove	-	-	-	-	-	-
Examination Room	-	-	-	-	-	-
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	-	-	-	-	-	-
X-ray, Fluoroscopy Room	-	-	-	-	-	-
X-ray, Treatment Room	-	-	-	-	-	-
Physical Therapy and Hydro-therapy	-	-	-	-	-	-
Soiled Utility	-	-	10	-	-	-
Clean Utility	-	-	10	-	-	-
Autopsy	-	-	10	No	-	-
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	-	-	-	No	-	-
Bedpan Room	-	-	10	-	-	-
Bathroom	-	-	10	-	-	-
Janitors' Closet	-	-	10	-	-	-
Sterilizer Equipment Room	-	-	10	-	-	-
Linen and Trash Chute Rooms	-	-	10	No	-	-
Laboratory, General	-	-	-	-	-	-
Laboratory, Media Transfer	-	-	-	-	-	-
Food Preparation Centers	-	-	10	-	-	-
Warewashing	-	-	-	-	-	-
Dietary Day Storage	-	-	-	-	-	-
Laundry, General	-	-	10	No	-	-
Soiled Linen	-	-	10	No	-	-
Clean Linen	-	-	10	No	-	-
Anesthesia Storage	E	Optional	8	No	-	-
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	-
Clean Workroom	-	-	-	-	-	-
Unsterile Supply Storage	-	-	-	-	-	-

TABLE 2.6.19: STATE OF NEW MEXICO

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recircu-lation	Percent Humidity	Temperature (°F)
Operating Room	-	-	-	-	50	75
Emergency Operating Room	-	-	-	-	50	75
Delivery Room	-	-	-	-	50	75
Nursery Suite	-	-	-	-	55	75
Recovery Room	-	-	-	-	-	70
Intensive Care	-	-	-	-	-	70
Patient Room	-	-	-	-	-	70
Patient Corridor	-	-	-	-	-	70
Isolation Room	-	-	-	-	-	70
Isolation Alcove	-	-	-	-	-	70
Examination Room	-	-	-	-	-	70
Medication Room	-	-	-	-	-	70
Pharmacy	-	-	-	-	-	70
Treatment Room	-	-	-	-	-	70
X-ray, Fluoroscopy Room	-	-	-	-	-	70
X-ray, Treatment Room	-	-	-	-	-	70
Physical Therapy and Hydro-therapy	-	-	-	-	-	70
Soiled Utility	-	-	-	No	-	70
Clean Utility	-	-	-	No	-	70
Autopsy	-	-	-	-	-	70
Workroom	-	-	-	-	-	70
Warefrigerated Body Holding Room	-	-	-	-	-	70
Toilet Room	-	-	-	No	-	70
Bedpan Room	-	-	-	-	-	70
Bathroom	-	-	-	No	-	70
Janitors' Closet	-	-	-	No	-	70
Sterilizer Equipment Room	-	-	-	-	-	70
Linen and Trash Chute Rooms	-	-	-	No	-	70
Laboratory, General	-	-	-	-	-	70
Laboratory, Media Transfer	-	-	-	-	-	70
Food Preparation Centers	-	-	-	No	-	70
Warewashing	-	-	-	No	-	70
Dietary Day Storage	-	-	-	No	-	70
Laundry, General	-	-	-	No	-	70
Soiled Linen	-	-	-	No	-	70
Clean Linen	-	-	-	No	-	70
Anesthesia Storage	-	-	-	-	-	70
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	70
Clean Workroom	-	-	-	-	-	70
Unsterile Supply Storage	-	-	-	No	-	70

TABLE 2.6.20: STATE OF NORTH CAROLINA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recircu-lation	Percent Humidity	Temperature (°F)
Operating Room	-	-	-	-	-	70
Emergency Operating Room	-	-	-	-	-	70
Delivery Room	-	-	-	-	-	70
Nursery Suite	-	-	-	-	-	70
Recovery Room	-	-	-	-	-	70
Intensive Care	-	-	-	-	-	70
Patient Room	-	-	-	-	-	70
Patient Corridor	-	-	-	-	-	70
Isolation Room	-	-	-	-	-	70
Isolation Alcove	-	-	-	-	-	70
Examination Room	-	-	-	-	-	70
Medication Room	-	-	-	-	-	70
Pharmacy	-	-	-	-	-	70
Treatment Room	-	-	-	-	-	70
X-ray, Fluoroscopy Room	-	-	-	-	-	70
X-ray, Treatment Room	-	-	-	-	-	70
Physical Therapy and Hydro-therapy	-	-	-	-	-	70
Soiled Utility	-	-	-	-	-	70
Clean Utility	-	-	-	-	-	70
Autopsy	-	-	-	No	-	70
Workroom	-	-	-	-	-	70
Warefrigerated Body Holding Room	-	-	-	-	-	70
Toilet Room	-	-	-	No	-	70
Bedpan Room	-	-	-	-	-	70
Bathroom	-	-	-	No	-	70
Janitors' Closet	-	-	-	-	-	70
Sterilizer Equipment Room	-	-	-	-	-	70
Linen and Trash Chute Rooms	-	-	-	-	-	70
Laboratory, General	-	-	-	-	-	70
Laboratory, Media Transfer	-	-	-	-	-	70
Food Preparation Centers	-	-	-	No	-	70
Warewashing	-	-	-	No	-	70
Dietary Day Storage	-	-	-	No	-	70
Laundry, General	-	-	-	-	-	70
Soiled Linen	-	-	-	-	-	70
Clean Linen	-	-	-	-	-	70
Anesthesia Storage	E	-	8	No	-	70
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	70
Clean Workroom	-	-	-	-	-	70
Unsterile Supply Storage	-	-	-	-	-	70

TABLE 2.6.21: STATE OF NORTH DAKOTA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	12	No (1)	50-60	70-76
Emergency Operating Room	P	5	12	No (1)	50-60	70-76
Delivery Room	P	5	12	No (1)	50-60	70-76
Nursery Suite	P	5	12	No (1)	50	75
Recovery Room	E	2	6	No (1)	50-60	75
Intensive Care	P	2	6	No (1) (2)	30-60	70-80
Patient Room	E	2	2	Optional	-	75
Patient Corridor	E	2	4	Optional	-	75
Isolation Room	E	2	6	No (2)	-	75
Isolation Alcove	E	2	6	No (2)	-	75
Examination Room	-	-	-	-	-	75
Medication Room	-	-	-	-	-	75
Pharmacy	-	-	-	-	-	75
Treatment Room	E	2	6	No	-	75
X-ray, Fluoroscopy Room	N	2	6	No	-	75
X-ray, Treatment Room	E	2	6	Optional	-	75
Physical Therapy and Hydrotherapy	N	2	6	Optional	-	75
Soiled Utility	N	2	4	No	-	75
Clean Utility	P	2	4	Optional	-	75
Autopsy	N	2	12	No	-	75
Workroom	-	-	-	-	-	75
Warefrigerated Body Holding Room	-	-	-	-	-	75
Toilet Room	N	Optional	10	No	-	75
Bedpan Room	N	Optional	10	No	-	75
Bathroom	N	Optional	10	No	-	75
Janitors' Closet	N	Optional	10	No	-	75
Sterilizer Equipment Room	N	Optional	10	No	-	75
Linen and Trash Chute Rooms	N	Optional	10	No (4)	-	75
Laboratory, General	N	2	6	Optional	-	75
Laboratory, Media Transfer	P	2	4	No	-	75
Food Preparation Centers	E	2	10	No (4)	-	75
Warewashing	N	Optional	10	No (4)	-	75
Dietary Day Storage	E	Optional	2	No (4)	-	75
Laundry, General	E	2	10	No (4)	-	75
Soiled Linen	N	Optional	10	No	-	75
Clean Linen	P	2	2	Optional	-	75
Anesthesia Storage	E	Optional	8	No	-	75
Central Medical and Surgical Supply						
Soiled Room	N	2	4	No	-	75
Clean Workroom	P	2	4	Optional	-	75
Unsterile Supply Storage	E	2	2	Optional	-	75

TABLE 2.6.22: STATE OF OKLAHOMA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	-	-	-	No	-	70
Emergency Operating Room	-	-	-	No	-	70
Delivery Room	-	-	-	No	-	70
Nursery Suite	-	-	-	No	-	70
Recovery Room	-	-	-	-	-	70
Intensive Care	-	-	-	-	-	70
Patient Room	-	-	-	-	-	70
Patient Corridor	-	-	-	-	-	70
Isolation Room	-	-	-	No	-	70
Isolation Alcove	-	-	-	No	-	70
Examination Room	-	-	-	-	-	70
Medication Room	-	-	-	-	-	70
Pharmacy	-	-	-	-	-	70
Treatment Room	-	-	-	-	-	70
X-ray, Fluoroscopy Room	-	-	-	-	-	70
X-ray, Treatment Room	-	-	-	-	-	70
Physical Therapy and Hydrotherapy	-	-	-	-	-	70
Soiled Utility	-	-	-	No	-	70
Clean Utility	-	-	-	No	-	70
Autopsy	-	-	-	No	-	70
Workroom	-	-	-	-	-	70
Warefrigerated Body Holding Room	-	-	-	-	-	70
Toilet Room	-	-	-	No	-	70
Bedpan Room	-	-	-	No	-	70
Bathroom	-	-	-	No	-	70
Janitors' Closet	-	-	-	No	-	70
Sterilizer Equipment Room	-	-	-	No	-	70
Linen and Trash Chute Rooms	-	-	-	-	-	70
Laboratory, General	-	-	-	No	-	70
Laboratory, Media Transfer	-	-	-	No	-	70
Food Preparation Centers	-	-	-	No	-	70
Warewashing	-	-	-	No	-	70
Dietary Day Storage	-	-	-	No	-	70
Laundry, General	-	-	-	No	-	70
Soiled Linen	-	-	-	No	-	70
Clean Linen	-	-	-	No	-	70
Anesthesia Storage	-	-	-	No	-	70
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	70
Clean Workroom	-	-	-	-	-	70
Unsterile Supply Storage	-	-	-	-	-	70

TABLE 2.6.23: STATE OF SOUTH DAKOTA

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recircu-lation	Percent Humidity	Temperature (°F)
Operating Room	-	-	-	-	50-60	70
Emergency Operating Room	-	-	-	-	50-60	70
Delivery Room	-	-	-	-	50-60	70-76
Nursery Suite	-	-	-	-	50	75
Recovery Room	-	-	-	-	50-60	75
Intensive Care	-	-	-	-	30-60	70-80
Patient Room	-	-	-	-	-	75
Patient Corridor	-	-	-	-	-	75
Isolation Room	-	-	-	-	-	75
Isolation Alcove	-	-	-	-	-	75
Examination Room	-	-	-	-	-	75
Medication Room	-	-	-	-	-	75
Pharmacy	-	-	-	-	-	75
Treatment Room	-	-	-	-	-	75
X-ray, Fluoroscopy Room	-	-	-	-	-	75
X-ray, Treatment Room	-	-	-	-	-	75
Physical Therapy and Hydro-therapy	-	-	-	-	-	75
Soiled Utility	-	-	-	-	-	75
Clean Utility	-	-	-	-	-	75
Autopsy	-	-	-	-	-	75
Workroom	-	-	-	-	-	75
Warefrigerated Body Holding Room	-	-	-	-	-	75
Toilet Room	-	-	-	-	-	75
Bedpan Room	-	-	-	-	-	75
Bathroom	-	-	-	-	-	75
Janitors' Closet	-	-	-	-	-	75
Sterilizer Equipment Room	-	-	-	-	-	75
Linen and Trash Chute Rooms	-	-	-	-	-	75
Laboratory, General	-	-	2	-	-	75
Laboratory, Media Transfer	-	-	2	-	-	75
Food Preparation Centers	-	-	-	-	-	75
Warewashing	-	-	-	-	-	75
Dietary Day Storage	-	-	-	-	-	75
Laundry, General	-	-	-	-	-	75
Soiled Linen	-	-	-	-	-	75
Clean Linen	-	-	-	-	-	75
Anesthesia Storage	E	-	8	No	-	75
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	75
Clean Workroom	-	-	-	-	-	75
Unsterile Supply Storage	-	-	-	-	-	75

TABLE 2.6.24: STATE OF TEXAS

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	P	5	25 (10)	No (12)	50-60	70-76
Emergency Operating Room	P	5	25 (10)	No (12)	50-60	70-76
Delivery Room	P	5	12 (10)	No (12)	50-60	70-76
Nursery Suite	P	5	12	No (12)	30-60	75
Recovery Room	P	2	6	Optional	50-60	75
Intensive Care	P	2	6	Optional	30-60	75-80
Patient Room	-	-	-	-	-	-
Patient Corridor	-	-	-	-	-	-
Isolation Room	E	2	6	No (3)	-	-
Isolation Alcove	-	-	-	-	-	-
Examination Room	-	-	-	-	-	-
Medication Room	-	-	-	-	-	-
Pharmacy	-	-	-	-	-	-
Treatment Room	-	-	-	-	-	-
X-ray, Fluoroscopy Room	-	-	-	-	-	-
X-ray, Treatment Room	-	-	-	-	-	-
Physical Therapy and Hydrotherapy	-	-	-	-	-	-
Soiled Utility	-	-	10	-	-	-
Clean Utility	-	-	10	-	-	-
Autopsy	-	-	10	-	-	-
Workroom	-	-	-	-	-	-
Warefrigerated Body Holding Room	-	-	-	-	-	-
Toilet Room	-	-	10	-	-	-
Bedpan Room	-	-	10	-	-	-
Bathroom	-	-	10	-	-	-
Janitors' Closet	-	-	10	-	-	-
Sterilizer Equipment Room	-	-	10	-	-	-
Linen and Trash Chute Rooms	-	-	10	No	-	-
Laboratory, General	N	-	-	-	-	-
Laboratory, Media Transfer	-	-	-	-	-	-
Food Preparation Centers	-	-	10	-	-	-
Warewashing	-	-	10	-	-	-
Dietary Day Storage	-	-	10	-	-	-
Laundry, General	-	-	10	-	-	-
Soiled Linen	-	-	10	-	-	-
Clean Linen	-	-	10	-	-	-
Anesthesia Storage	-	8	8	No	50	70
Central Medical and Surgical Supply						
Soiled Room	-	-	-	-	-	-
Clean Workroom	-	-	-	-	-	-
Unsterile Supply Storage	-	-	-	-	-	-

TABLE 2.6.25: STATE OF WASHINGTON

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recirculation	Percent Humidity	Temperature (°F)
Operating Room	-	-	-	No	-	70
Emergency Operating Room	-	-	-	No	-	70
Delivery Room	-	-	-	No	-	70
Nursery Suite	-	-	-	No	-	70
Recovery Room	-	-	-	No	-	70
Intensive Care	-	-	-	No	-	70
Patient Room	-	-	-	-	-	70
Patient Corridor	-	-	-	-	-	70
Isolation Room	-	-	-	-	-	70
Isolation Alcove	-	-	-	-	-	70
Examination Room	-	-	-	-	-	70
Medication Room	-	-	-	-	-	70
Pharmacy	-	-	-	-	-	70
Treatment Room	-	-	-	-	-	70
X-ray, Fluoroscopy Room	-	-	-	-	-	70
X-ray, Treatment Room	-	-	-	-	-	70
Physical Therapy and Hydrotherapy	-	-	-	-	-	70
Soiled Utility	-	-	10	-	-	70
Clean Utility	-	-	10	-	-	70
Autopsy	-	-	10	-	-	70
Workroom	-	-	-	-	-	70
Warefrigerated Body Holding Room	-	-	-	-	-	70
Toilet Room	-	-	10	-	-	70
Bedpan Room	-	-	-	-	-	70
Bathroom	-	-	10	-	-	70
Janitors' Closet	-	-	-	-	-	70
Sterilizer Equipment Room	-	-	10	-	-	70
Linen and Trash Chute Rooms	-	-	10	-	-	70
Laboratory, General	-	-	10	-	-	70
Laboratory, Media Transfer	-	-	10	-	-	70
Food Preparation Centers	-	-	10	-	-	70
Warewashing	-	-	-	-	-	70
Dietary Day Storage	-	-	-	-	-	70
Laundry, General	-	-	10	-	-	70
Soiled Linen	-	-	10	-	-	70
Clean Linen	-	-	10	-	-	70
Anesthesia Storage	E	-	8	No	-	70
Central Medical and Surgical Supply						
Soiled Room	-	-	10	-	-	70
Clean Workroom	-	-	10	-	-	70
Unsterile Supply Storage	-	-	10	-	-	70

TABLE 2.6.26: STATE OF WISCONSIN

Area Designation	Relative Pressure	Air Changes Outdoor Air Per Hour	Total Air Changes Per Hour	Recircu-lation	Percent Humidity	Temperature (°F)
Operating Room	P	6	6	Optional	-	70
Emergency Operating Room	P	6	6	Optional	-	70
Delivery Room	P	6	6	Optional	-	70
Nursery Suite	P	6	6	Optional	-	75
Recovery Room	P	6	6	Optional	-	75
Intensive Care	-	-	-	Optional	-	75
Patient Room	-	-	-	Optional	-	75
Patient Corridor	-	-	-	Optional	-	75
Isolation Room	P	6	6	Optional	-	75
Isolation Alcove	P	6	6	Optional	-	75
Examination Room	-	-	-	Optional	-	-
Medication Room	-	-	-	Optional	-	-
Pharmacy	-	-	-	Optional	-	-
Treatment Room	-	-	-	Optional	-	-
X-ray, Fluoroscopy Room	-	-	-	Optional	-	-
X-ray, Treatment Room	-	-	-	Optional	-	-
Physical Therapy and Hydro-therapy	-	6	6	Optional	-	75
Soiled Utility	-	-	-	Optional	-	60
Clean Utility	-	-	-	Optional	-	-
Autopsy	-	6	6	No	-	60
Workroom	-	-	-	Optional	-	-
Warefrigerated Body Holding Room	-	-	-	Optional	-	-
Toilet Room	-	-	-	Optional	-	75
Bedpan Room	-	-	-	Optional	-	60
Bathroom	-	-	-	Optional	-	75
Janitors' Closet	-	-	-	Optional	-	-
Sterilizer Equipment Room	-	-	-	Optional	-	60
Linen and Trash Chute Rooms	-	-	-	Optional	-	-
Laboratory, General	-	-	-	Optional	-	67
Laboratory, Media Transfer	-	-	-	Optional	-	-
Food Preparation Centers	-	-	-	Optional	-	-
Warewashing	-	-	-	Optional	-	-
Dietary Day Storage	-	-	-	Optional	-	-
Laundry, General	-	-	-	Optional	-	60
Soiled Linen	-	-	-	Opitonal	-	60
Clean Linen	-	-	-	Optional	-	-
Anesthesia Storage	-	-	-	Optional	-	60
Central Medical and Surgical Supply						
Soiled Room	-	-	-	Optional	-	-
Clean Workroom	-	-	-	Optional	-	-
Unsterile Supply Storage	-	-	-	Optional	-	-

Chapter 3

ROLE OF AIR IN HOSPITAL-ACQUIRED INFECTIONS

Historic man has always had the tendency to implicate the unseen or unknown as the cause of his illness. Explanations of disease were based on observations and circumstances such as the weather and did not always properly relate cause and effect. For example, the terms miasmas, meaning noxious vapors, and malaria, meaning bad air, were often implicated as the cause of disease. The church and religion also played a strong role in determining men's thinking. Good and evil spirits were always present and cures to a particular disease could be effected through appeasement of the evil spirit. As religious thinking progressed, man still associated disease with religion but transferred the responsibility to the good spirit and disease then became the consequence of sin while cure was affected by appeasing a wrathful god. Disease was also related to the incomprehensible physical environment such as motion of the stars and earthquakes.

In 1546, Fractorius published his theory of contagion and explained that transmission of infections might occur by air. From that time on, the concept of airborne disease was developed. Pasteur, in 1861, demonstrated the existence of air spores. In 1869, Joseph Lister attempted to sterilize the atmosphere with carbolic acid in operating rooms since he believed airborne bacteria were a major source of infection. In 1917, Stillman reported that he had cultured the same type of pneumococci from

patients as isolated from dust in their homes. In 1934, Wells developed the concept of droplet nuclei, which essentially is that smaller droplets (less than 100-200μ) expelled from the mouth would remain suspended whereas the larger droplets would fall to the ground before evaporating. He demonstrated that a variety of pathogens, including streptococci, pneumococci, coliform organisms, and influenza virus, could be atomized into a chamber and remain viable in the resultant aerosols for hours or even days. He extended his ideas to the hypothesis that droplet nuclei were the primary mode for the spread of measles and proceeded to test his ideas by installing ultraviolet lights in schoolrooms theorizing that the measles virus would be killed and hence, reduce the infection rate. A number of other workers, notably O.H. Robertson and J.E. Perkins in this country and a large group in Great Britain, extended the concept of ultraviolet disinfection to army barrackes where influenza, streptococci and upper respiratory tract disease were rampant among recruits.[341] However, during and subsequent to this period increasingly detailed epidemiological studies pointed more and more toward the importance of close personal association rather than the air in the spread of this group of infections in hospitals and barracks.[352]

During the last 25 years, systematic epidemiological studies supported by extensive laboratory studies in experimental animals and human subjects have established the existence of airborne spread of certain naturally occurring diseases. These include: psittacosis, Q fever, histoplasmosis, coccidiomycosis, anthrax, brucellosis, and pulmonary tuberculosis. In addition, infection by inhalation of microbial aerosols has been shown to be a major hazard in research laboratories. Certain procedures involving infectious agents are notoriously dangerous. These

include: intra-nasal inoculation of animals, grinding of tissues in a blender, or concentrating microorganisms in a centrifuge. Extensive precautions against aerial contamination are now standard practice in laboratories.

Airborne spread is an important route of infection in the hospital; however, the probable importance of airborne transfer in relation to other modes of spread often becomes a matter of judgment rather than direct evidence.[311] It is important therefore, to briefly discuss the epidemiology of airborne infections.

EPIDEMIOLOGY OF AIRBORNE INFECTIONS

The acquistion of an infection involves five stages: 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.

With the advent of sulfonamides and antibiotics, it was thought that the problems of infections would become obsolete. However, in the 1950s and early 1960s bacteria, especially, Staphylococcus aureus promptly developed an increased virulence and resistance to many of the antibiotics. S. aureus is still a common pathogen but the majority of infections today are usually caused by gram-negative organisms.

Until the late 1960s most epidemiological studies focused primarily on coagulase positive staphylococcus, but these studies are not necessarily applicable to the other organisms that also cause infection. It should be noted that there is often no correlation between the amount of Staphylococcus aureus in the air, and the total amount of bacteria. Also, the total number of bacteria is not a good indicator of the occurrence of possible pathogenic bacteria in the air.[179] Hospital personnel and patients are the major reservoirs for most pathogens. For example, there are nasal carriers of staphylococci and streptococci and E. coli dispersals occur via the fecal-oral route. Fomites, inaminate objects in the hospital environment, have been implicated in pseudomonas and other gram-negative infections.

Neither the frequency with which normal individuals harbor Staphylococcus aureus in the nose and on the skin, nor the reason for the wide variation in the number of staphylococci shed into the air by carriers is well known. Hare and Ridley, 1958, showed that very few staphylococci are liberated into the air directly from the nose of carriers during ordinary activity and later emphasized the importance of desquamated epithelium to act as a carrier of staphylococci.[334] The liberation of bacteria during shaking of bedclothing has been

amply demonstrated by Girdlestone, 1951, and Solberg, 1965.[331, 344] Nurses'gowns and operating room clothing have been implicated in the shedding of bacteria.[310] Human or vehicular traffic will also increase bacterial dispersal from dusty surfaces.[322] Although many workers have estimated the bacterial content of floors, the actual transfer by this route has not been demonstrated.[348].

The particle size of microbial aerosols is a major factor in the occurrence of airborne infection whether natural, accidental or experimental. Small particles, less than about 5μ in diameter pass through the nose and pharynx, down the trachea into the far reaches of the lungs to the terminal bronchioles and alveoli. Many of these small particles are trapped there, beyond the point where they can be removed by ciliary action of the bronchial epithelium. In contrast, particles larger than about 5μ are trapped in the nose and throat or elsewhere in the respiratory tract and cannot reach the alveoli. Experimental studies have shown that the number of small particles necessary to infect through the alveoli are very small, often ten organisms or less, whereas the dose necessary to infect with larger particles through the upper respiratory tract are great, often exceeding 5,000.

Studies by Noble, 1963, have indicated that the mean "equivalent diameter" of particles carrying Staphylococcus aureus was about 14μ.[216] This is consistant with the idea that most airborne Staphylococcus aureus cells are associated with desquamated fragments of skin and thus, are too large to penetrate to the lung alveoli.

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. Indications of some loss of infectivity due to temperature and humidity have been reported while others have found no such effect. (See Chapter 5)

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. The major cause of respiratory infections is the aspiration of fluid from the pharynx (during anesthesia, intoxications and other conditions when the cough reflex is depressed). Introduction of bacteria via humidifiers, nebulizers, and respirators may also cause respiratory infection. Many authors argue that sedimentation from the air onto a scalpel blade, however, is unlikely to introduce more than a few organisms.[185]

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 air in hospital acquired infections, in relation to other factors and to apply effective control to the most important routes; those routes which transfer the majority of the pathogens.

FACTORS OTHER THAN AIR THAT INFLUENCE INFECTION RATES IN SURGERY

The Committee on Control of Surgical Infections of the Pre and Postoperative Care Committee of the American College of Surgeons have classified surgical wounds into the following categories:

Class I. Clean operative wound. A non-traumatic wound in which no inflammation was encountered, no break in technique occurred, and respiratory, alimentary, and genitourinary tracts were not entered.

Class II. Clean, contaminated operative wounds. A non-traumatic wound in which minor break in technique occurred or in which gastrointestinal, genitourinary or respiratory tracts were entered without significant spillage.

Class III. Contaminated operative wound. Any fresh traumatic wound from a relatively clean source or an operative wound in which there is a major break in technique, gross spillage from the gastrointestinal or entrance into the genitourinary or biliary tracts in the presence of infected urine or bile.

Class IV. Dirty operative wound. A traumatic wound from a dirty source or with delayed treatment, fecal contamination, foreign body or retained devitalized tissue.

Clean wounds have a 2% infection rate on the average while dirty wounds average a 30% infection rate regardless of the aseptic technique used.[354] In these instances it is most likely endogenous not exogenous flora causing infection. There are numerous factors other than air which are associated with surgical risk, six of which will be discussed here. This list is by no means comprehensive.

Age. Increasing age has been demonstrated to have a definite effect on the rate of operative wound infection as shown in a prospective study in 1964 by the National Academy of Sciences. The infection rate of all ages in that study was 7.4%. The lowest rate of 4.7% occurred in the 15-24 year old group and the highest rate of 10.7% occurred in the 65-74 year old range. Adjustment of the data to include different wound types, duration of surgery, diabetes and obesity did not alter these conclusions. The increased incidence of surgical infection at the extremes of the age range has been postulated to be a result of decreased antibody production or ineffective phagocytosis and intracellular killing of bacteria by neutrophils.[355,356]

Sex. Neither sex nor race appears to be a primary determinant of risk for differences in wound classification. 355,356

Nutritional State. The incidence of postoperative infection appears to be increased by the extremes in the nutritional state of the patient. In the National Academy of Sciences study, severe obesity was associated with an infection rate of 8.1% This is much higher than the average infection rate and the rate doesn't decrease when adjusted for the longer operating time required in the obese patient. The apparent susceptibility of obese persons to wound infections is attributed to the relative avascularity of adipose tissue.

Severe malnutrition was associated with a higher incidence of wound infection. It is thought that polymorphonuclear leucocytes in these patients have reduced phagocytic activity and a defect in intracellular bactericidal capacity.355, 356.

Diabetes. Diabetes mellitus has long been thought to decrease host resistance to infection. The study by the National Academy of Sciences showed that this alleged propensity to infection did not exist and that the age-adjusted rate of wound infection was similar to the non-diabetic group. However, other studies dispute this claim.[355,356]

Length of Hospitalization. An increased incidence of infection is directly related to the length of hospitalization and the duration of the operative procedure. This applies to all classifications of wounds including clean procedures.[355,356]

Personal Hygiene. The shedding of bacteria can be decreased dramatically by good personal hygiene habits of the surgical staff. Washing with chlorhexadiene or hexachlorophene can reduce shedding of viable organisms from 1,000,000 particles to almost nill. Not only should the surgeon wash his hands but it is also recommended that the surgeon shower and wash his axilla and perineum before surgery. In England during some operations surgeons cover their perineum with vaseline or wear rubber diapers to inhibit shedding. A study by Cruse has shown that if the patient did not shower before surgery the infection rate was 2.6%. If he showered before the operation using soap the infection rate was 2.1% and if he showered using an antiseptic detergent containing hexachlorophene the infection rate fell to 1.3%. In patients who had the operation site shaved, the infection rate was 2.5%. In patients who had no shave but had their operation site clipped, the infection rate fell to 1.7%. For those patients who had no shaving or clipping the infection rate was .9%. Furthermore, in patients on whom depilatory creams were used instead of shaving the infection rate was .6%.[356]

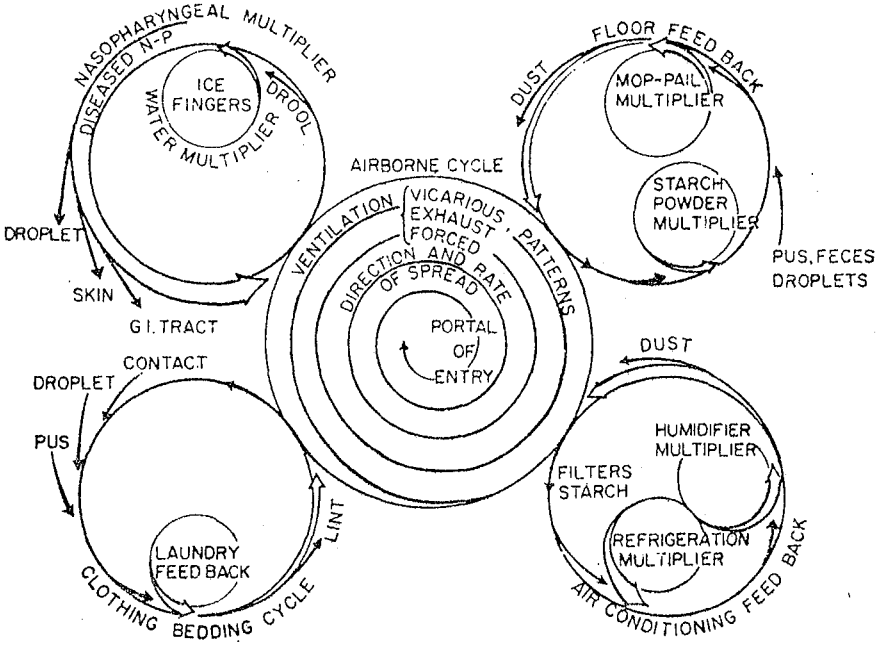
It can be seen from some of this information that factors other than air greatly enhance or diminish infections in hospitals. The information dealing with surgical patients can also be extrapolated to other patients remembering that the personal hygiene habits of doctors and nurses and patients affect the status of infection outside surgery as well as in it.

AIR AS A SOURCE OF NOSOCOMIAL INFECTION

The very nature of a hospital where many people are brought into intimate contact in a close community provides numerous possibilities for the exchange of microorganisms by indirect and direct contact or by airborne transmission. The sources of potentially pathogenic microorganisms in hospitals are numerous. It has already been reported that most of the organisms recovered from the air at any one time have been freshly disseminated from skin of people through normal activity. Organisms have also been isolated from mechanical systems such as humidifiers, that disseminate air. Linen chutes have been implicated as sources of bacteria on wards due to the chimney effect of the vertical chute and the piston effect of loads of contaminated laundry dropping in the chute.[202] Aspergillus infections were linked to a reservoir of fungus growing in the fire proofing insulation around pipes and ventilation ducts.[103] Air filters and ceiling tiles have also been named as potential reservoirs of bacteria and fungus in hospitals. The specific organisms involved and the magnitude of the contamination in each segment of the hospital environment seem to vary according to sampling methods and other local variables including temperature, humidity, air movement, traffic and

physical structure of the hospital, as well as a seemingly endless list of the clinical characteristics of the patients in the sampled area such as age, underlying illness,and antimicrobial usage.

Transfer within the environment is, or may be, a very complex process. The possible routes are very numerous and can be direct or labarynthian. Figure 3.1 is a diagram of the many routes of transmission for bacteria in hospitals. The surfaces throughout the entire hospital are of paramount importance as reservoirs of bacteria that contaminate the environment in which the hospital population lives. [291]



-Vortex of environment sepsis. (From Walter CW[7])

Figure 3.1

The ability to precisely document the movement of bacteria from one segment of the environment to another (e.g., from the nares of a Staphylococcus aureus carrier to the wound of another patient) is fraught with many

technical difficulties, and demonstrating that airborne transmission of a specific organism occurs more frequently or more readily than any other possible mode is extremely difficult.[359]

Solberg, 1978, reports that the route of infection differs from microorganism to microorganism; it differs from one place to another depending on what has been done to eliminate sources and to close other avenues of transfer, and it differs under the previous conditions from time to time.

Methods Use to Study Air.

It appears from a review of the literature that there is no consistently applied method used to study air. Settling plates of different sizes, large volume air samplers, and slit air samplers were employed for varying amounts of time to quantify bacterial contamination. Thus, a great need exists for standardization of technique and for development of laboratory methods that will reliably sample the environemnt in differing situations. Even in studies focusing on Staphylococcus aureus not all authors used phage typing as epidemiological markers.[359]

Studies using phage typing often found that the one phage type that predominated in nosocomial infections was never recovered from the air.[218] Several workers using these variable methods have then extrapolated the association of air with a high number of staphylococci to the possibility of a high infection rate.

The simple demonstration that a pathogenic organism has been deposited on a settling plate or is present upon analysis of an Andersen Air Sampler is insufficient evidence to implicate the air as the mode of transmission.

The Importance of Airborne Infection. Airborne transmission of infectious diseases has often been demonstrated in hospital wards. Wells and Riley, 1961, clearly demonstrated the importance of this route of transmission for

pulmonary tuberculosis. Ehrenkranz, 1972, reports that on a ward where a patient with undetected tuberculosis bronchopneumonia spent 2 1/2 days, there were 21 infections in 60 former tuberculin-negative personnel (35%).[82] Ten had little or no direct contact with the patient and were likely to have been infected by the spread of Mycobacterium tuberculosis through an unbalanced air conditioning system that lacked high-efficiency filters. Airborne spread of smallpox can take place over at least 1-2 floors (Mechede), and epidemics of measles spread via the airborne route have been reported from several hospitals. However, the part played by airborne transmission in most viral infections is far from clear, and more studies are needed.

Several investigators have attempted to differentiate the relative roles of operating rooms and wards in the acquisition of hospital acquired infections. Most favor the predominance of the operating room, despite the fact that the wound is subject to a series of manipulations during the postoperative period in the ward environment.[335,37,338,272] Because most of the literature has evolved around the operating room, many of the following examples have been taken from these reports.

Airborne Infection In Surgery. There have been many reports in the literature on the airborne transmission of staphylococcal infection during surgery over the last 20 years. Ayliffe and Collins, 1968, studied 251 operations carefully and identified seven patients whose postoperative Staphylococcus aureus infections stemmed from an orderly who was the only one in the surgical room who carried this very rare phage type.[20] Since the orderly had no patient contact but stayed in the periphery of the room, the infection most likely was airborne. Walter and colleagues, 1963, reported a similar event in which two

of 169 patients developed postoperative wound infections following exposure to a carrier who was gowned and masked and remained on the periphery of the operating room and had no contact with the patients.[348] The route of infection was in all likelihood airborne since no other carrier of this specific phage type was found among the operating room personnel. A later report by Hambraeus found a specific strain of staphylococcus carried only by the anesthesiologist resulting in two surgical infections, probably implicating the airborne route.[130] These reports, however, do no establish the relative importance of this route of infection compared to other routes.

Unfortunately, many of the other studies of this type had noticeable shortcomings. Infection was defined by clinical evaluation, yet data was not presented by correlating any source or mode of transmission (air) with infections and patient colonization or infection and/or other sources of infection were not conclusively eliminated.[276] Another example is a study conducted by Wehrle, 1970, where airborne transmission of smallpox was epidemiologically implicated by the use of a smoke generator simulation test. During the smoke generation test, the windows of both primary and secondary cases were open, but the authors did not note whether the windows had been open during the epidemic.

If the premise that the airborne route exists is to be accepted, the magnitude of its role in producing disease must then be determined. Seropian, 1966, studied the importance of airborne contamination as a factor in postoperative wound infection between two hospitals and found overall infection rates were lower in Hospital #2 than in Hospital #1 in spite of significantly higher airborne colony counts in Hospital

#2.[257] Bernard and Cole, 1962, could demonstrate no correlation between air contamination and the incidence of wound infection in clean surgical procedures. Data presented by Oldstine, 1966, along with the experimental information that large numbers of staphylococci must be incorporated into a wound to cause infection (Elek, 1956), make it unlikely that fallout of organisms, even from heavily contaminated air, play a role in the transmission of staphylococcal infection.[218,328] In a comprehensive study on the relationship between the bacterial flora found in the operating room air and the bacterial flora found in postoperative wound infection, the ad hoc committee of the National Research Council concluded that there was no correlation (Committee On Trauma 1964).[324]

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 at least 10 times more frequently than the transfer of tracer particles.[181] The conclusion was that the number of staphylococci found elsewhere in the ward could not be accounted for by airborne transmission alone. A detailed study of nursing procedures has shown that the nurses' uniforms become heavily contaminated with bacteria after contact with an infected patient. During a nursing procudure, the direct transfer could be as high as 300 colony forming units (cfu) per one-third meter^2.[127] Marples and Kligman, 1975, have shown that about 400 cfu of staphylococci represents an

infectious dose when the upper layer of the skin has been removed by tape.[196] Thus the direct transfer during nursing may represent the infectious dose rather than air alone. Spears, 1969, reported similar observations.[345]

Many experiments show that the number of organisms transmitted by hand contact may be very large compared to the numbers transmitted by air. In a study by Mortimer, 1966, airborne transmission probably occurred among colonized infants, but direct contact, which was shown to be minimized by handwashing appeared to play a greater role.[206] A group of susceptible newborns was exposed to a group of newborns who were colonized with Staphylococcus aureus.

> *One nursery without physical barriers was divided so that one nursing team had contact with the susceptible (airborne) group only, while another team had contact with a group of both susceptible (close contact) and index infants. The rate of transmission from index infants to susceptible infants, between whom there was no physical contact, was 6-10 percent. In contrast, the rate of transmission from index infants to those susceptible infants cared for by the nursing team was 43 percent when no handwashing was performed. When nurses washed their hands after caring for an infant, the rate of transmission within the group fell to 14 percent.*[359]

Reduction of direct airborne transfer of microorganisms from one area to another would appear to be of clinical advantage only where transfer by other routes is significantly less than that by the direct airborne route.

The simple mechanical act of handwashing has long been recognized as the most important procedure in the prevention of nosocomial infections.[357,358] The most predominate site of nosocomial infections is the urinary tract, followed by the lower respiratory tract, intravenous catheter-associated bacteremias, neonatal skin infections, and surgical wound infections.[354] Organisms are transmitted from the hands of medical personnel during certain procedures and cause infections at these sites.[206] Many different types of infections may therefore be prevented following appropriate handwashing.

The role of exogenous bacteria has been discussed and more recently the role of endogenous bacteria has come to attention especially in view of the critically ill and immuno-suppressed patient. Because of these patients and because of complex orthopedic and cardiac procedures that are being performed, laminar airflow systems have been designed and studied.

LAMINAR AIRFLOW IN SURGERY

The use of laminar airflow systems in the operating room is considered to be one of the most controversial issues in surgery today. The term laminar flow compounds the controversy since true laminar flow cannot exist in the operating room. In a true laminar airflow system, the entire body of air within a confined area moves at a uniform velocity along parallel lines. In the operating room, however, persons or objects, such as the surgeon or the equipment disturb the

air pattern, and the air becomes turbulent. As turbulence develops,the levels of airborne contamination at critical work sites can be significantly altered.[99] There seems to be little question that the concentration of airborne bacteria can be reduced in rooms with unidirectional airflow. The assumption was made that a reduction in airborne contamination would result in a reduction of microbial contamination of the surgical wound, and presumably a reduction in the incidence of postoperative wound infection. From a review of the literature, it appears that other factors than laminar air flow systems are involved and that many surgeons have had good results without laminar airflow systems.

Franco and coworkers, 1976, measured the effect of laminar airflow systems and aspiration suits on airborne contamination and wound contamination in orthopedic surgery.[92] Analysis of the data showed that the laminar airflow system indeed reduced the number of airborne particles by about a factor of five, but that there was no correlation between the level of microbial contamination of the air and microbial contamination of the wound when operations were performed in laminar airflow or conventional airflow operation rooms.

Several investigations support the findings of Franco. McLauchlan, 1976, found no difference in infection rates when hip replacement surgery was performed in ultraclean and plenum-ventilated operating rooms.[198] Hambraeus, 1967, also reduced the air contamination in the operating room without effecting any change in wound infection rates.[130] Irvine,

1974, performed 100 hip joint replacements in laminar airflow and 100 in conventional airflow, and an equal number of infections occurred in each group.[336] In none of the cases did the bacteria isolated from the infected wound match those of the air in either the laminar flow or conventional room, although the ambient bacterial counts in the laminar flow room were greatly reduced from those of the conventional room. It was concluded that laminar flow had no advantage over conventional ventilation. Schonholtz, 1976 and French, 1973, both report that infection rates are proportional to the duration of the operation and the number of staff in the room, and inversely proportional to the air changes per hour.[248,102] Laufman, 1973, reports that after thousands of hip replacement operations in conventional operating rooms without laminar flow chambers, a number of American orthopedic surgeons have a combined two-year infection rate of 0.45%, a figure as low as, or lower than that reported by surgeons with comparable numbers of operations performed in laminar flow chambers.[170] In yet another survey, Haslam, 1974, shows that conventional air conditioning systems with proper filtering and airflows can provide atmospheres with bacterial contamination of the same order of magnitude as those with the special air handling devices.[137]

Many hospitals point to work done by Charnley when arguing for laminar air flow operating rooms. After more than 6,000 operations, Charnley reported a decrease in the infection rate from 7% to 0.5%.

Charnley, 1970, felt that this reduction was due to operation in clean air.[54] It must be noted however, that the largest drop in infection rates came when Charnley moved from a naturally ventilated (open windows) operating room to a plenum ventilated operating room. During the study they also improved technique, altered criteria for surgery, used a new skin disinfectant, gloves, closely woven gowns (to limit the penetration of skin bacteria) and enforced aseptic technique more rigidly. As can be seen, no hard, statistical data are universally agreed upon that prove or disprove that a clean air system decreases the infection rate. While the laminar flow room can reduce the number of infections, there remains no substitute for strict aseptic technique, careful patient preparation, and gentle tissue handling.

Formal papers presented at meetings and those published over the past several years have suggested that operating room particle counts might be equated with airborne bacteria and therefore with the potential for wound infection. In practice, however, particle counts in the air do not seem to correlate with the incidence of wound infection. Evidence is abundantly available to indicate that airborne microbes over the wound site can be diminished practically to zero without significant effect on the already low infection rates. Studies that do purport to show reduced infection rates do not correlate the infections with airborne bacteria, but to the types of bacteria found on the skin. The rare cases of infections traced to airborne bacteria are the ones that gain most attention because they tend to be reported. In an overwhelming majority of these reports, the cause is an unusual situation, such as a malfunctioning or erroneously constructed ventilating system, or to an exceptionally heavy shedder or carrier in the room, or to some combination of unusual circumstances any of which are

equally harmful in the presence of laminar flow. Moreover, absence of bacteria in the air does not necessarily mean the absence of bacteria on the particles settling on instruments and gloves, nor the absence of penetration of bacteria through apparel.

The use of published studies to collect data is hampered by a number of contraints: the low incidence of known rates of wound infection and poorly controlled studies; data from simulated situations are difficult to interpret; differences in methods of data collection; inadvertant distortion of conclusions by bias for, or defense of, either a method or a system (as exemplified by opposing points of view that used the same data for support but arrive at opposite conclusions); and differences in types of source material (kinds of surgery, techniques, dead space, tissue ischemia, constricting sutures, the condition of a patient, etc.). Because of the relatively low contribution of any one factor to an already low incidence of infection, alteration of factors such as air, technique, time of day, or length of operation, can be adjusted only after an enormous number of cases in order to have real significance. The number of cases required to prove the significance of one factor upon such a low incidence event as wound infection has been variously estimated at between 2,000 and 5,000 consecutive cases of precisely the same kind of operation under precisely the same conditions, except for the one variable being tested. This would be an extremely tedious exercise and would not allow for any new developments in either method or system. 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 air should be kept as clean as economically possible.[110]

CONTROLLING BACTERIA BY MEANS OTHER THAN LAMINAR FLOW

Although infections remain a problem in hospitals, the best means to control or eliminate them remains a subject of controversy. Let us now take a brief look at other ways of cleaning the air in hospitals. The level of bacterial contamination in a given space is dependent on the nature of the activity, the cleanliness and quantity of air being supplied, the quality of housekeeping, and the numbers and activity levels of personnel. One method of effectively controlling airborne bacteria in the modern hospital is by adequately filtering the air, particularly in operating rooms, delivery rooms, burn wards, nurseries, and other surgical wards. Particulate reduction in the so-called soiling range of measurements responds almost directly to the efficiency of the filters employed, (electrostatic precipitators, fibrous media, etc.) values for which have been well established. Recommendations for filters used in hospitals include: an efficiency of not less that 95%; durable, airtight fit to prevent air leakage; a prefilter of at least 30% upstream of other air conditioning equipment, and proper space for maintenance.

The numbers of electrostatic precipitators used in the United States grows annually, yet there is reluctance on the part of some authorities to use this equipment. Precipitators produce measureable amounts of ozone, which has been suggested to cause a slowing of certain body processes. By the time the ozone is dispersed and diffused into the volume of air in the system, however, its concentration is believed to be reduced sufficiently so as not to constitute a nuisance or a hazard.

Another excellent method of air cleansing involves recirculation through activated carbon filters. Many state and local building codes will allow a greater portion of air to be recirculated if carbon filters are utilized. but these are not presently applicable to hospitals. It should be noted

that there is a great variety of carbons and various depths can be used.[317] Furthermore, carbon gives very little indication when it is worn out and not longer functioning and therefore, it must be monitored.[339] Air scrubbing, air washing and air incineration have all been tried. Other concepts of air cleaning have been reviewed by Decker and colleagues, 1962.[326]

Studies have also been conducted to test the effectiveness of air disinfection by ultraviolet irradiation. Ultraviolet irradiation has been found to decrease the postoperative infection rate by some observers, whereas others have seen little or no reduction, even though the number of viable organisms was significantly reduced in the air.[136,315,324,333,346] A problem associated with UV use is radiation reactions such as erythema and conjunctivitis which requires the use of extensive protective clothing for patients and personnel. It was reported that as many as 30 irradiators were required in the air ducts to achieve a purity comparable to that obtainable by adequate filtering. Since microorganisms can be protected by dust particles, ultraviolet irradiation was not a satisfactory method for air purification. Ultraviolet radiation in classrooms has not reduced the incidence of the common cold. In a study conducted at Cincinnati General Hospital, the infection rate with ultraviolet lights was 7.4% compared to 7.5% when dummy lamps were used.[347] Riley, 1971, has demonstrated that with no increase in air motion, a single 30-w tube increased the disappearance of organisms from the lower part of a room by the equivalent of 61 air changes per hour.[233, 234] With a ceiling fan, the same ultraviolet tube almost doubled the rate of disappearance of organsims. He concludes that rates of ventilation that suffice to control

temperature and humidity can be complemented by ultraviolet to effect removal of airborne bacteria. Here again, review of the literature fails to present a correlation of airborne bacteria and infection rates and to indicate which route is of major importance in postoperative infections.

The role of air engineering and ventilation should be placed in perspective among other risk factors. Unless other hygienic measures such as installations of air locks, and the use of accessible easily cleaned fittings with smooth surfaces are also taken, ventilation by air under pressure tends to facilitate rather than to prevent the spread of micro-organisms in a hospital.[122] 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. While no one will deny that in tackling the multifactorial nature of nosocomial infections, every effort should be made to render each potential cause as harmless as possible, review of the literature indicates that while air may be one of the modes of transmission, it is most likely a minor one in most instances, and never the most important element. McLauchlan, 1976, adds that to argue to the contrary is somewhat analogous to the claim that it is safer to drink dangerously contaminated water from a sterile glass.[198] 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 adherance to protective isolation procedures of patients with serious illnesses for whom the airborne route may play a significant role in the transmission of disease.

CONCLUSION

It is quite clear that the situation in a hospital is so complex that it is very difficult to draw any precise conclusions concerning the effect of ventilation on infection rates. There are many studies which strongly indicate that wound infections are due to airborne dispersal from an identified carrier. These reports do not, however, establish the relative importance of this route of infection compared to other routes. Many experiments have studied the role of airborne versus direct contact transmission and have concluded that airborne organisms accounted for a smaller proportion of bacterial transmission than the transmission by direct contact.

In an experiment using tracer particles, it was found that the transfer of staphylococci occurred at least ten times more frequently than tracer particles, suggesting that the staphylococci were transferred by other routes than the airborne route alone. Ventilation may affect the transfer of bacteria and the level of contamination, but whether or not it affects infection rates depends on the relative importance of the airborne route of transfer in a given situation. Most of the evidence also points to the fact that laminar flow is less effective than adherance to proper techniques by the surgical team and support personnel in the operating room and the ward environment.

References

1. AACH, R. D., J. EVANS and J. LOSE. An epidemic of infectious hepatitis possibly due to airborne transmission. American Journal of Epidemiology, 87: 99-109, 1968.

2. ADAMS, R., B. FAHLMAN, E. W. DUBE, F. J. C. DUBE and S. READ. Control of infections within hospitals. Journal of the American Medical Association, 169: 1557-1567, 1959.

3. AGLIETTI, P. et al. Effect of a surgical horizontal unidirectional filtered air flow unit on wound bacterial contamination and wound healing. Clinical Orthopaedics and Related Research, 101: 99-104, June 1974.

4. AGLIETTI, E. A., E. A. SALVATI and P. D. WILSON, JR. A study of the effectiveness of a surgical unidirectional filtered air flow unit during total prosthetic replacements of the hip. Archiv fur Orthopaedische Undfall-Chirurgic, 77: 257-268, 1973.

5. Airborne infections: a review by the personnel of Naval Laboratory Research Unit #1. War Medicine, 4: 1-30, 1943.

6. ALEXAKIS, P. G., P. G. FELDON, M. WELLISCH, R. E. RICHTER and S. M. FINEGOLD. Airborne bacterial contamination of operative wounds. Western Journal of Medicine, 124: 361-369, 1976.

7. ALEXANDER, J. W. Energy concepts in the control of surgical infections. Surgery, 75(6): 934-946, 1974.

8. ALLANDER, C. and E. ABEL. Ventilation in the hospital. Sjukhuset (Goteberg), 43(10): 234-236, October 1966.

9. ALLER, H. F. Air hygiene for hospitals. II. Efficiency of fibrous filters against staphylococcic droplet nuclei and bacteria-bearing dust. Journal of the American Medical Association, 170: 261-267, 1959.

10. Alter, H. Air conditioning in intensive care units. Munch Med Wochenschr, 112(44): 17-20, October 1970.

11. American Public Health Association. Committee on environment of hospitals and other medical care facilities. Guidelines for hospital operating and delivery room air conditioning systems. American Journal of Public Health, 57(6): 1053-1054, June 1967.

12. AMSTUTZ, H. C. High velocity directional air flow systems (HVDAFS). Western Journal of Medicine, 122(2): 154-155, 1975.

13. ANDERSON, K. Pseudomonas pyocyanea disseminated from an air cooling apparatus. Medical Journal of Australia, April 1959.

14. ANSELMI, U. Air conditioning installations in intensive therapy units. Condizionamento dell'Aria, Riscaldamento, Refrigerazione, 15(4): 227-230, April 1971.

15. ANSELMI, U. Air conditioning plant for a burns unit. Nuova Tecnica Ospedaliera, 8(3): 99-102, March 1965.

16. ANSELMI, U. Considerations and suggestions on the merit of air conditioning in a large burns centre. Condizionamento dell' Aria, Riscaldamento, Refrigerazione, 15(5): 308-311, May 1971.

17. ANSPACH, W. E. Local air blanket protection of surgical wounds to prevent airborne contamination. Cleveland Clinic Quarterly, 40(4): 229-239, 1973.

18. ASLUND, B., L. ERNEROT and E. SANDELL. Examination of the air hygiene in the pharmacy. Acta Pharmaceutica Suecica, 11: 25-32, February 1974.

19. AULICIEMS, A. Thermal requirements of secondary school children in winter. Journal of Hygiene, 67: 59-65, 1968.

20. AYLIFFE, G.A.J., B.J. COLLINS, E.J.L. LOWBURY and M. WALL. Protective isolation in a single bedroom: studies in a modified hospital ward. Journal of Hygiene, 69(4): 511-527, December 1971.

21. BAIRD, G. and W. WHYTE. Air-movement control for treatment and isolation rooms. Journal of Hygiene 67(2): 225-232, June 1969.

22. BAKELS, M. and W. E. ANSPACH. Is clean air necessary? NAT News, 11(7): 25, 27, 30, September 1974.

23. BALDWIN, M. and D. G. FOX. Laminar flow for the neurosurgical operating room. Journal of Neurosurgery, 29(6): 660-665, December 1968.

24. BALLARD, W. D. The problem of control of airborne contamination in hospital design. Contamination Control, 7(2): 9-23, February 1968.

25. BARCLAY, T.L. and F. DEXTER. Infection and crossinfection in a new burns centre. British Journal of Surgery, 55: 197, 1968.

26. BARTON, F. L. et al. Atmospheric contamination in intensive therapy units: the role of mechanical ventilation. Anesthesia, 28(2): 160-163, March 1973.

27. BECHTOL, C.O. The use of total vertical laminar air systems in surgery. Contamination Control, 9(10): 18-22, September/October 1971.

28. BECK, W.C. A new integrator for monitoring time and temperature of steam sterilizers. Medical Instrumentation, 10: 293-296, 1976.

29. BECK, W.C. Operating room aerobiology. Gruthrie Clinical Bulletin, 33: 126-132, 1964.

30. BECK, W.C. Special air systems: the case for laminar flow. Medical Instrumentation, 10: 275-276, 1976.

31. BECK, W. C. and F. FRANK. The open door in the operating room. American Journal of Surgery, 125(5): 592-595, May 1973.

32. BERBEE, G.A.M., R. VanFURTH and W.C. NOBLE. Endemic infection in surgical wards. Journal of Hygiene, 75: 185-194, 1975.

33. BERNARD, H. R., W. R. COLE and J. C. CLAYWELL. Recirculation of air in the surgical suite. Hospitals, 35: 46-50, 1961.

34. BERNARD, H. R., R. SPEERS, F. O'GRADY and R. A. SHOOTER. Reduction of dissemination of skin bacteria by modification of operating room clothing and by ultraviolet irradiation. Lancet, 2: 458-461, 1975.

35. BLAKEMORE, W. S., G. J. McGARRITY, R. J. TURNER, H. W. WALLACE, H. MacVAUGH and L. L. CORIELL. Infection by airborne bacteria with cardiopulmonary bypass. Surgery 70: 830, 1971.

36. BLAKEMORE, W. S. Special air systems for operating rooms. Bulletin American College of Surgeons. 57: 18, 1972.

37. BLOWERS, R. et al. Control of wound infection in a thoracic surgery unit. Lancet, 269: 786-794, December 1955.

38. BLOWERS, R. et al. Ventilation of operating theatres. Journal of Hygiene, Cambridge, 58(4): 427-444, December 1960.

39. BODEY, G. P. and E. J. FREIREICH. Laminar air flows: use for patients with leukemia. Contamination Control of Biomedical Environments, 9+, September/October 1972.

40. BODEY, G. P. and B. GEWERTZ. Microbiological studies of a laminar air flow unit for patients. Archives of Environmental Health, 19(6): 798-805, December 1969.

41. BOLTON, N. E., T. A. LINCOLN, J. A. OTTEN and W. E. POTTER. A method for biological testing of containment systems for viral agents. American Industrial Hygiene Association Journal, 37(7): 427-431, 1976.

42. BONCEY, J. M. and W. R. L. BROWN. A study of the aerial contamination of a pharmacy department and its relationship to the method of ventilation. Journal of Hospital Pharmacy, 30: 160-164, June 1972.

43. BOROVIK, E. G. et al. Hygienic investigations of air exchange in hospitals. Gigiena i Sanitariya, (12): 12-15, December 1975.

44. BOULTON, C. Horizontal air flow unit. Nursing Times, 72(5): 197-198, February 1976.

45. BOURDILLON, R. B. et al. Air Hygiene in dressing-rooms for burns or major wounds. Lancet, 250: 601-605, April 1946.

46. BUCHBERG, H. et al. Evaluation and optimum use of directed horizontal filtered air flow for surgeries. Clinical Orthopedics, 111: 151-155, September 1975.

47. BUCHBERG, H. and G. P. LILLY. Model studies of directed sterile air flow for hospital isolation. Annals of Biomedical Engineering, 2(1): 102-122, March 1974.

48. BUTLER, P. R. Letter: Choice of ventilating system for operating theatres. Lancet, 2: 100-101, July 1971.

49. CALIA, F. M., E. WOLINSKY, E. A. MORTIMER, J. S. ABRAMS and C. H. RAMMELKAMP. Importance of the carrier state as a source of Staphylococcus aureus in wound sepsis. Journal Hygiene, 67: 49-57, 1969.

50. CANZLER, B. Air conditioning in the hospital. Krankenhaus Umschau, 39(3): 217-218, March 1970.

51. CAPLAN, K. J. Energy conservation by recirculation of cleaned air. ASHRAE Transactions, 83(1): 615-624, 1977.

52. CECCATELLI, M. Air conditioning plant for operating suites. Nuova Tecnica Ospedaliera, 8(3): 103-105, March 1965.

53. CHARNLEY, J. Letter: Clean air operating room enclosures. British Medical Journal, 4: 224-245, October 1974.

54. CHARNLEY, J. Letter: Operating theatre ventilation. Lancet, 1(655): 1053-1054, May 1970.

55. CHARNLEY , J. and N. EFTEKHAR. Postoperative infection in total prosthetic replacement arthroplasty of the hip joint with special reference to the bacterial content of the air of the operating room. British Journal of Surgery, 56: 641, 1971.

56. CLARK, R. E., W. C. AMOS, V. HIGGINS, K. F. BEMBERG and C. S. WELDON. Infection control in cardiac surgery. Surgery 79: 89-96, 1976.

57. CLARK, R. E. Laminar flow vs. conventional ventilation in operating rooms: results of a 3 year study of airborne bacteria in a large hospital. Surgery Forum, 24: 33-35, 1973.

58. CLARK, R. P. Air conditioning in hospital wards and operating theatres. Engineering in Medicine, 6(1): 12-16, January 1977.

59. COLE, W. R., H. R. BERNARD and D. L. GRAVENS. Control of airborne bacteria in operating rooms. Hospitals, 39(6): 79-80, 82, 84, March 1965.

60. COLLIN, P., C. EMERY and R. V. E. GWILLIAM. Proceedings: A Climatic "chamber" for use with a laboratory operating table. Journal of Physiology, 256: 3-4, March 1976.

61. COOK, R. and N. A. BOYD. Reduction of the microbial contamination of surgical wound areas by sterile laminar air-flow. British Journal of Surgery, 58(1): 48-52, January 1971.

62. CORIELL, L. L. and G. J. McGARRITY. Elmination of airborne bacteria in the laboratory and operating room. Bulletin of the Parenteral Drug Association, 21(2): 46-54, March/April 1967.

63. CORIELL, L. L., G.J.McGARRITY and J. HORNEFF. Medical applications of dust free rooms: elimination of airborne bacteria in a research laboratory. American Journal of Public Health, 57(10): 1824-1836, 1967.

64. CORIELL, L. L., W. S. BLAKEMORE and G. J. McGARRITY. Medical applications of dust free rooms. II. Elimination of airborne bacteria from an operating theater. Journal of the American Medical Association, 203: 1038-1046, 1968.

65. COUCH , R. B. et al. Effect of route of inoculation on experimental respiratory viral disease in volunteers and evidence for airborne transmission. Bacteriological Reviews, 30(3): 517-531, 1966.

66. CUCCHI, L., A. AUGUSTI and M. GALEANE. The significance of staphylococcal air pollution in operating rooms. Architectural Ital Chir, 95(5): 673-683, 1969.

67. CUMMING, W. J. Proceedings: clean air operating enclosures. Journal of Bone Joint Surgery; 57(2): 248-249, May 1975.

68. DAHLBACK, O. Air treatment and surgery. Krankenhaus Umschau, 34(7): 267-270, July 1965.

69. DAVIS, R. N. Health authorities evaluate laminar flow concept for hospital applications. Hospitals, 41: 87, August 1967.

70. DECKER, H. M., L. M. BUCHANAN, L. B. HALL and K. R. GODDARD. Air filtration of microbial particles. American Journal of Public Health, 53: 1982-1988.

71. Definition of surgical microbiologic clean air. American College of Surgeons Bulletin, pg. 19-21, Janaury 1976.

72. DEMUTH, N. L. Factors to consider in evaluating OR air conditioning systems. Hospital Topics, 46: 111-112, April 1968.

73. DEMUTH, N. L. Fight airborne infection 5 ways in pharmaceutical lab and plant. Heating, Piping & Air Conditioning, 37(3): 117-121, March 1965.

74. DIXON, E. D. The role of airborne bacteria in theatre acquired surgical wound infection. Cleveland Clinical Quarterly, 40: 115, 1973.

75. DMITRIEVA, R. A. et al. The role of air currents in the spread of respiratory viral infections on hospital premises. Mikrobiol Epidemiol Immunobiol, 5: 14-17, 1974.

76. DOBROWOLSKI, J. Characteristics of the atmosphere of operating and treatment rooms in Bialystock hospitals and clinics. Szpitalnictwo Polskie, 10(1): 17-21, January/February 1966.

77. DOWLING, H. F. Airborne infections - the past and the future. Bacteriological Reviews, 30(3): 485-487, 1966.

78. DRAZEN, E. C. and A. S. LEVINE. Laminar airflow rooms. Hospitals, 88: 88-93, January 1974.

79. DRURY, M. and V. E. SKEEG. The Greenwich district hospital scheme. IHVE Journal, 36: 359-369, March 1969.

80. DUELL, R. C. and R. M. MADDEN. Droplet nuclei produced during dental treatment of tubercular patients. Oral Surgery, 30: 711, 1970.

81. EDDINS, E. W. Clean air room. Southern Hospitals, 41: 14, July 1973.

82. EHRENKRANZ, N. J. and J. L. KICKLIGHTER. Tuberculosis outbreak in a general hospital: evidence for airborne spread of infection. Annals of Internal Medicine, 77: 377-382, 1972.

83. ELLIOTT, T. Microbial control in spotlight at AACC Meeting. Heating, Piping & Air Conditioning, 39: 140-141, September 1967.

84. ELLISON, J. Use. of recirculating air conditioners to clean the air of small wards. Thorax, 20(2): 146-148, March 1965.

85. ELSWORTH, R., R. C. TELLING and J. W. S. FORD. Sterilization of air by heat. Journal of Hygiene, 54: 445-457, 1955.

86. ELVINGSSON, C. O. Ventilation in clean areas. Sjukhuset 44(1): 13-20, January 1967.

87. ENGLEY, F. B. The persistence (survival) of microorganisms: I. airborne organisms. Texas Reports Biological Medicine 4: 712-757. 1955.

88. ESDORN, H. Air flow and pressures in hospital rooms. Gesundheits-Ing, 9(10): 289-299, October 1973.

89. Evaluation: Laminar flow operating rooms. Health Devices, 1(12): 272-276. 292+, 1972.

90. FAGAN, A. Laminar flow clean rooms gaining popularity. Dimensions in Health Service, 51(4): 52-55, April 1974.

91. FALLON, K. Problems of getting clean air into surgery. Actual Specifying Engineer, 31: 66-70, May 1974.

92. FANCO, J. A., H. BAER and W. F. ENNEKING. Airborne contamination in orthopedic surgery. Clinical Orthopedics and Related Research, 122: 231-243, 1976.

93. FEINBERG, S. M. Allergies and air conditioning. American Journal of Nursing, 66: 1333-1336, June 1966.

94. FIELD, A. A. Operating theater air conditioning. Heating, Piping and Air Conditioning, 45: 91-94, 1973.

95. FOORD, N. and O. M. LIDWELL. Airborne infection in a fully air conditioned hospital: I. air transfer between rooms. Journal of Hygiene, 75(1): 15-30, 1975.

96. FOORD, N. and O. M. LIDWELL. Airborne infection in a fully air conditioned hospital: II. transfer of airborne particles between rooms resulting from the movement of air from one room to another. Journal of Hygiene. 75(1): 31-44, 1975.

97. FOORD, N. and O. M. LIDWELL. The control by ventilation of airborne bacterial transfer between hospital patients, and its assessment by means of a particle tracer. I. an airborne-particle tracer for cross infection studies. Journal of Hygiene, 70: 279-286, 1972.

98. FOX, D. G. and M. BALDWIN. Contamination levels in a laminar flow operating room. Hospital, 42(2): 108-112, 1968.

99. FOX, D. G. An empirical study of the application of a horizontal unidirectional airflow system for a hospital operating room. [Doctoral dissertation, University of Minnesota] 1967.

100. FOX, D. G. A study of the application of laminar flow ventilation to operating rooms. Public Health Monograph No.78: Public Health Service Publication No. 1894, 7: 1-14, 1977.

101. FREEMAN, M.A.R., J. H. CHALLIS, J. ZELEZONSKI and I. D. JARVIS. Sepsis rates in hip replacement surgery with special reference to the use of ultra clean air. Archiv fur orthopadische und unfall-Chirurgie, 90: 1-14, 1977.

102. FRENCH, M.L.V. et al. A system analysis to postoperative wound infections, Phase II: A microbiological assessment of the exogenous bacterial controls in the operating room. Cleveland Clinic Quarterly, 40(4): 221-227.

103. Fungal threat traced to ceiling insulation. Hospital Infection Control, 3: 89-92, July 1976.

104. GANO, H. L. This filtered air system cuts surgical infections. Modern Hospital, 104(1): 136-138, January 1965.

105. GARDNER, R. C. and C. B. LAVTER. The least you should know about laminar air flow. Consultant, 12: 120-123, June 1972.

106. GAULIN, R. P. Design features affecting asepsis in the hospital. DHEW/Public Health Service 930-D-9; 10pp., 1966.

107. GLAWAGGER, F. Room climate and fungi growth in hospitals. Arch Hyg Bakteriol, 536-538, December 1968.

108. GLENN, J.N. and F. W. RECKLING. Avoiding infections: clean air operating rooms. Journal of the Kansas Medical Association, 73(3): 123-124, March 1972.

109. GODDARD, K. R. Do self-contained units present a hazard to ICU patients. Heating, Piping and Air Conditioning, January 1971.

110. GOHR, F. A. Air cleanliness. Journal of Environmental Health, 32(4): 448-449, January 1970.

111. GOLDBERG, L. J. Application of microaerofluorometer to the study of dispersion of a fluorescent aerosol into a selected atmosphere. Journal Applied Meteorology, 7: 68-72.

112. GOLDFINCH, D. A. Air conditioning in hospitals. Official Architecture and Planning, 29(3): 439-440, March 1966.

113. GOLIS, M. V. et al. On pollution at the air of the operation theater. Khirurgiia, 47(1): 83-85, 1971.

114. GOODRICH, E. O. Air environment in the operating room. American College of Surgeons, 55: 7+, June 1970.

115. GOODRICH, E. O. Jr. Total airborne particulate contamination in a community hospital. Medical Research Engineering, 7(3): 23-24, 1968.

116. GOULD, J. C., F. J. BONE and J. H. S. SCOTT. The bacteriology of surgical theatres with and without unidirectional airflow. Bulletin De la Societe Internationalale de Chirurgie, 33: 53-60, January/ February 1974.

117. GRIEBLE, H. G., T. J. BIRD, H. M. NIDEA and C. MILLER. Chute-hydropulping waste disposal system. A resrvior of enteni bacilli and pseudomonas in a modern hospital. Journal of Infectious Diseases, 130: 602, 1974.

118. GRITSCHKE, R. O. Environmental control for surgical suites. Heating, Piping and Air Conditioning, 45(11): 71-75, October 1973.

119. GROUNDS, M. C. Laminar air flow: Vertical or horizontal? AORN Journal, 16: 72-76.

120. GUBERNSKII, Y. D. and N. S. ORLOVA. Hygienic studies or standardizing the microclimate of operating rooms and wards equipped with a panel radiation heating system. Gigiena i Sanitariia, 37(2): 22-25, 1972.

121. GUNDERMANN, K. O. The bacterial content of various hospital departments. Zentralbl Bakteriol Orig B., 159(3): 231-243, 1974.

122. GUNDERMANN, K. O. The evaluation of artificial ventilation installations in infectious diseases wards. Archiv fur Hygiene und Bakteriologie, 151(1/2): 58-63, May 1967.

123. HALL, L. B. and H. M. DECKER. IV. Procedures applicable to sampling of the environment for hospital use. American Journal of Public Health. 50: 491-496, 1960.

124. HALL, L. B. and K. R. GODDARD. Air filtration of microbial particles. Department of Health Education and Welfare, June 1962.

125. HALLECK, F. E. Hospital microbicidal processes. Medical Instrumentation, 10: 297-299, 1976.

126. HAMBRAEUS, A. and H. F. SANDERSON. The control by ventilation of airborne bacterial transfer between hospital patients, and its assessment by means of a particle tracer. III. Studies with an airborne-particle tracer in an isolation ward for burned patients. Journal of Hygiene, 70: 299-312, 1972.

127. HAMBRAEUS, A. Transfer of Staphylococcus aureus via nurses' uniforms. Journal of Hygiene, 71: 799-814, 1973.

128. HAMBRAEUS, A. Dispersal and transfer of Staphylococcus aureus in an isolation ward for burned patients. Journal Hygiene, 71: 787, 1973.

129. HAMBRAEUS, A. and J. G. LAURELL. Infections in a burn unit. Contributions Microbiology and Immunology, 1: 459, 1973.

130. HAMBRAEUS, A., S. BENGTSSON and G. LAURELL. Bacterial contamination in a modern operating suite. I. Effect of ventilation on airborne bacteria and transfer of airborne particles. Journal of Hygiene, 79: 121-132, 1977.

131. HAMMOND, E. C. Ammonium alginate wool as a filter for collecting microorganisms from large volumes of air. Journal of General Microbiology, 19: 267-270, 1958.

132. HAMPSON, J. H. R. Operating theatre air conditioning. Heating and Ventilating Engineer and Journal of Air Conditioning. 38(445): 67-72, August 1964; 38(445): 142-147, September 1964.

133. HARSTAD, J. B., J. M. DECKER and A. G. WEDUM. Use of ultraviolet irradiation in a room air conditioner for removal of bacteria. Applied Microbiology, 2: 148-151, 1954.

134. HARSTAD, J. B., H. M. DECKER, L. M. BUCHANAN and M. E. FILLER. Air filtration of submicron virus aerosols. American Journal of Public Health, 57: 2186-2193, 1967.

135. HART, J. B. Airflow determination in a horizontal laminar airflow operating room. IEEE Transactions Biomedical Engineering, 21: 70-73, January 1974.

136. HART, D. Control of airborne pathogenic bacteria by bactericidal radiant energy. Modern Hospital, 46: 79-81, 1936.

137. HASLAM, K. R. Laminar airflow, air conditioning in the operating room: a review. Anesthesia and Analgesia Current Researches, 53(2): 194-199, 1974.

138. HECHT, N. S. Adapting the hospital to laminar flow. Hospital Forum, 16: 13-15, May 1973.

139. HEISE, J. G. Highly aseptic operating theatre through clean room air conditioning installation with low turbulence laminar flow. Klima-Kalte-Technik, 17(9): 189-194, September 1975.

140. HENDERSON, R. J. Staphylococcal infection of surgical wounds. The source of infection. British Journal of Surgery, 54: 756, 1967.

141. HERNDON, C. H. The clean air operating room at University Hospitals of Cleveland. Cleveland Clinic Quarterly, 40(4): 183-190, 1973.

142. HEROLD, H. Z. and V. COPEL-FRANKEL. Prevention of airborne Staphylococcal infection in an orthopedic surgical ward. Clinical Orthopedic and Related Research, 76: 194, 1971.

143. HIYSMANS-EVERS, A.G.M. Bacteriological and epidemiological investigations in a hospital. Archivum Chirurgicum Neerlandicum, 23: 25, 1971.

144. HOFFMAN, K. Bacteriological problems of air conditioning systems in hospitals. Oeffentiliches Gesundheitswesen, 35: 74-82, November 1973.

145. HOLMGREN, J. H. Debate the validity of laminar flow systems sought by some surgeons. Modern Health Care, 7: 68-69, 1977.

146. HOPTON, D. S. Investigation of wound protection by a sterile laminar air curtain. Journal of the Royal College of Surgeons of Edinburgh, 19: 98-103, March 1974.

147. Hospitals and related health facilities. ASHRAE Guide and Data Book, 15: 163-176, 1971.

148. HOWORTH, F. H. Air technology in medicine. Building Service Engineering, 42: 249-256, February 1975.

149. HUGHES, H. G. Chutes in hospitals. Canadian Hospital Association Journal, 41: 56, 1964.

150. HURST, V., M. GROSSMAN, F. R. INGRAM and A. E. LOWE. Hospital laundry and refuse chutes as a source of Staphylococci cross infection. Journal of the American Medical Association, 167: 1223, 1958.

151. HUSZAR, R. J. Air curtains for patient isolation. Journal of the American Medical Association, 207(3): 549-551, January 1969.

152. INTAG, C. E., H. A. WIEBE and C. L. PARTAIN. An investigation of the importance of air flow in control of post-operative infections. ASHRAE Journal, 17(2): 27-33, 1975.

153. JACHOWICZ, R. A comparison of two systems of ventilation for hospitals. Szpitalnictwo Polskie, 10(5): 217-223, September/October 1966.

154. JACKOWICZ, R. The speed and direction of air flow in gravity ventilation ducts from the hygienic point of view. Szpitalnictwo Polskie, 10(2): 59-62, March/April 1966.

155. JEPSEN, O. B. Laminar air flow in operation theatres. Ugeskr Laeger, 134(37): 1944-1947, September 1972.

156. JEPSEN, O. B., S. O. LARSEN and V. F. THOMSEN. Post operative wound sepsis in general surgery. Acta Chircurgica Scandinavia, 136: 261, 1970.

157. JOPKE, W. H. et al. Air conditioning reduces microbiologic levels in hospital dishwashing facilities. Hospital Progress, 53(8): 22-24, 26, 28, 30, August 1972.

158. KALIKA, P. W. et al. The re-use of interior air. ASHRAE Journal, 12: 44-48, November 1970.

159. KENSETT, R. G. Air conditioning-plant design for operating theatres. Hospital Engineering, 28: 4-6, June 1974; 28: 3-9, 11-12, July/August 1974, and 28(11): 18-19, 21-23, September 1974.

160. KETHLEY, T. W. and W. B. CROWN. Filters for the hospital operating room. Contamination Control 6(12): 12-13, 1967.

161. KINGSTON, D. et al. The epidemiology of the common cold. III. The effect of ventilation, air disinfecting and room site. Journal of Hygiene, 60: 341-352, 1962.

162. KNUTSON, V. A. Plant operation. Hospitals, 46(7): 171-174, 176, 1972.

163. KRASNOFF, I. R. Aspects of vertical laminar air flow as a hospital contamination barrier. University of Michigan Hospital, 1970.

164. KRUGER, D. and H. MELCHERT. Technological aspects of hygiene in planning and supervision of air conditioning plants for rooms with special cleanliness requirements. Drugs Made in Germany, 18(1): 3-10, 12-14, 19-22, 24, 26-28, March 1975.

165. KRYNSKI, S. et al. Cocci carriers among patients of a dermatology department. I. Characterization of cocci cultured from patients and their relationship to hospital air flora. Przegl Dermatol, 61: 141-146, March/April 1974.

166. KUPERS, G. R. Ventilating systems in operating theatres: aerodynamic and microbiological background. Klimaatbeheersing, 5(1): 14-20, Janaury 1976.

167. Laminar flow ventilation in an intensive therapy unit at South Mimms, Hertfordshire. Nursing Times, 64(39): 1317, September 1968.

168. LANDAHL, H. D. and S. BLACK. Penetration of airborne particulates through the human nose. Journal of Industrial Hygiene, 29: 269-277, 1947.

169. LANGMUIR, A. D. Airborne infection: how important for public health. I. A historical review. American Journal of Public Health. 54: 1666-1668, 1964.

170. LANGMUIR, A. D. Epidemiology of airborne infection. Bacteriology Review. 25: 173-181, 1961.

171. LAUFMAN, H. Confusion in application of steam air systems to operating rooms. Cleveland Clinic Quarterly, 40(4): 203-209, 1973.

172. LAUFMAN, H. Current status of special air handling systems in operating rooms. Medical Instruments, 7(1): 7-15, January/ February 1973.

173. LAUFMAN, H. Is laminar airflow necessary for prophylaxis against wound infection? Medical Instruments, 10(6): 269-274. November/December 1976.

174. LAUFMAN, H. The surgeon views environmental controls in the operating room. Hospital Topics, 47(7): 73-78, July 1969.

175. LEGG, R. C. Air transfer in hospital bedrooms. Building Science, 5(1): 41-50, July 1970.

176. LEIF, W. R. and A. P. KRUEGER. Studies on the experimental epidemiology of respiratory infections. I. An apparatus for the quantitative study of airborne respiratory pathogens. Journal of Infectious Disease, 87: 103-116, 1950.

177. LESKE, W. and H. W. HACKENBERG. Air hygiene investigations in stomatology work rooms. Zeitschrift fur die gesamte Hygiene und ihre Grenzgebiete, 14(7): 512-518, July 1968.

178. LIDWELL, O. M. Airborne infection in a fully air conditioned hospital: III. Transport of gaseous and airborne particulate material along ventilated passageways. Journal of Hygiene, 75(1): 45- 56, 1975.

179. LIDWELL, O. M. et al. Airborne infection in a fully air conditioned hospital: IV. Airborne dispersal of Staphylococcus aureus and its nasal acquistion by patients. Journal of Hgyiene, 75(3): 445-447, 1975.

180. LIDWELL, O. M. , I. D. G. RICHARDS and S. POLAKOFF. Comparison of three ventilating systems in an operating room. Journal of Hygiene, 65(2): 193-205, June 1967.

181. LIDWELL, O. M. and W. C. NOBLE. Fungi and clostridia in hospital air: the effect of air conditioning. Journal of Applied Bacteria, 39: 251-261, 1975.

182. LIDWELL, O. M. et al. Staphylococcal in thoracic surgery: experience in a subdivided ward. Journal of Hgyiene, Cambridge, 64(3): 321-337, September 1966.

183. LIDWELL, O. M. and A. G. TOWERS. Unidirectional ("laminar") flow ventilation system for patient isolation. Lancet, i: 347-350, February 1972.

184. LIDWELL, O. M. et al. The ventilation of operating-theatres. Journal of Hygiene, 58(4): 449-464, December 1960.

185. LIDWELL, O. M. Clean air, less infection. Hospital Engineering, 30: 9-17, 1976.

186. LIDWELL, O. M. The control by ventilation of airborne bacterial transfer between hospital patients, and its assessment by means of a particle tracer. II. Ventilation in a subdivided isolation unite. Journal of Hygiene, 70: 287-297, 1972.

187. LIDWELL, O. M. Air exchange through doorways. The effect of temperature, difference, turbulence and ventilation flow. Journal of Hygiene, 79: 141-154, 1977.

188. LIDWELL, O. M., S. POLAKOFF, J. DAVIES and J. H. HEWITT. Nasal acquisition of Staphylococcus aureus in a subdivided and mechanically ventilated ward: endemic prevalence of a single staphylococcal strain. Journal of Hygiene, 68: 417-433, 1970.

189. LITONSKI, B. Air conditioning as decontamination unit for the air of operating theatres. Zentralbl Babteriol, Orig B 159(3): 244-271, 1974.

190. LITSKY, W., J. W. MARTIN and B. Y. LITSKY. Solid waste: a hospital dilemma. American Journal of Nursing, 72: 1841, 1972.

191. LOWBURY, E. J. The persistance of dust in occupied rooms. Journal of Hgyiene, 48: 1-5, 1950.

192. LUCARELLI, G. Air conditioning in operating suites. Nuova Tecnica Ospedaliera, 9(8): 287-308, August 1966.

193. MacCLELLAND, D. C. Laminar air unit: Achiever or appeaser. AORN Journal 23(5): 766-771, April 1976.

194. MAISONNET, M. and M. MERLIER. Prevention of infections in thoracic and cardiovascular surgery. An operating room with laminar flow. Ann Chir Thorac Cardiovasc, 13(3): 235-238, September 1974.

195. MALY, J. and M. SAMKOVA. Pharmaceutical ways of utilizing clean rooms with laminar air flow. Farm Obz. 40, May 1971.

196. MARPLES, R. R. and A. M. KLIGMAN. Experimental staphylococcal infections of the skin of man. International Symposium on Staphylococci and Staph Infections, 755-760, 1975.

197. McKENDRICK, G. D. and R. T. EMOND. Investigation of cross infection in isolation wards of different design. Journal of Hygiene, 76(1): 23-31, February 1976.

198. McLAUCHLAN, J., J. R. C. LOGIE, H. G. SMYLIE and G. SMITH. The role of clean air in wound infection acquired during operation. Surgery, Gynecology and Obstetrics,143: 6-8, 1976.

199. McNALL, P. E. Practical methods of reducing airborne contaminants in interior spaces. Archives Environmental Health, 30: 552-556, 1975.

200. McWILLIAMS, R. M. Divided responsibilities for operating room asepsis: The dilemma of technology. Medical Instrumentation, 10: 300-301, 1976.

201. MICHAELSEN, G. S. Design and maintenance of operating room air conditioning and ventilating systems as reported by maintenance engineers. American Journal of Public Health,51(12): 1896-1902, 1961.

202. MICHAELSEN, G. S. Designing linen chutes to reduce spread of infections organisms. Hospitals(JAHA), 39: March 1965.

203. MICHAELSEN, G. S., D. VESLEY and M. M. HALBERT. Laminar flow studied as aid in care of low-resistance patients. Hospitals(JAHA), 41: 91-103, 1967.

204. MICHAELSEN, G. S. Ventilation system maintenance practices: Report of a survey. Hospitals, February 1962.

205. MORRIS, C. Medical-legal implications of clean air systems. Cleveland Clinic Quarterly, 40(4): 161-181, 1973.

206. MORTIMER, E. A., E. WOLINSKY, A. J. GONZAGA and C. H. RAMMELKAMP. Role of airborne transmission in staphylococcal infections. British Medical Journal, 1: 319, 1966.

207. MUZZI, A. and M. NICOLI. Sterile rooms for hospital use: hygienic and functional problems. Nuovi Annali d'lgiene e Microbiologia, 23(6): 454-478, November/December 1972.

208. NELSON, C. L., T. L. GAVIN and J. SCHWARTZ. Bacteriological evaluation of a clean air system. Journal Soc Environ Eng., 14(4): 13-15, December 1975.

209. NELSON, J. P. et al. Horizontal flow operating room clean rooms. Cleveland Clinic Quarterly, 40: 191-202, 1973.

210. NELSON, J. P. OR clean rooms. AORN Journal, 15: 71-73, May 1972.

211. NELSON, C. L. Clean air systems. Contemporary Surgery, 6: 44-48, 1975.

212. NELSON, J. P. Five years experience with operating room clean rooms and personnel isolator systems. Medical Instrumentation, 10: 277-281, 1976.

213. NEUGART, H. Air conditions in an operating theatre with laminar flow in the wound area. Sulzer Tech Rev, 57(1): 75-79, 1975.

214. NEUGART, H. Air conditions in an operating theatre with vertical laminar flow in the operating field. Heizung-Luftung-Haustechnal-Duesseldorf, 25(11): 389-392, November 1974.

215. A new ventilation system for cleaner operating theatres. Moderna Sjukhus, 1(1): 44-45, 1966.

216. NOBLE, W. C., O. M. LIDWELL and D. KINGSTON. The size distribution of airborne particles carrying micro-organisms. Journal of Hygiene, 61: 385-391, 1963.

217. O'GRADY, F. Airborne infection and hospital design. British Hospital Journal, Social Services Review, 75: 700-702, April 1965.

218. OLDSTINE, M.B.A. Hospital acquired staphylococcal infection. Role of airborne organisms 9 month review of all admissions and surgical procedures. American Surgery, 32: 391, 1966.

219. OSTERTAG, H. Hygienic supervision of air conditioned aseptic areas in hospitals. *Zentralbl Bakteriol*, 157(1): 1-22, 1975.

220. PANNKOKE, T. Modern clean room concepts. Heating, Piping and Air Conditioning, 63-70, 1973.

221. PELLEU, G. B., W. B. SHREUE and L. W. WACHTEL. Reduction of microbial concentration in the air of dental operating rooms: I. High-efficiency particulate air filters. Journal of Dental Research, 49: 315-319, March/April 1970.

222. PENLAND, W. Z. and S. PERRY. Portable laminar-air-flow isolator. Lancet, 1: 174-176, January 1970.

223. PHILPOTT, C. M., J. W. SCHRADER and P. M. LAST. Airborne bacteria in open and air conditioned surgical wards. Medical Journal of Australia, 50-51, January 1969.

224. POLAKOFF, S., I.D.G. RICHARDS, M.T. PARKER and O. M. LIDWELL. Nasal and skin carriage of Staphylococcus aureus by patients undergoing surgical operation. Journal of Hygiene, 65: 1967.

225. POLLOCK, N. L. et al. Laminar air purge of microorganisms in dental aerosols. Journal of the American Dental Association, 81(5): 1131-1139, November 1970.

226. PORTER, K. W. Laminar flow comes under attack. Hospitals, 46: 142+, October 1972.

227. PROCTOR, D. F. Airborne disease and the upper respiratory tract. Bacteriological Reviews, 30(3): 498-513, 1966.

228. RECKZEH, G. and W. DONTENWILL. The problem of quantitative determination of airborne microorganisms in air conditioning systems as found in a laboratory animal unit for research built on the barrier system. Zentralbl Bakteriol Orig B, 157(2): 27-56, 1973.

229. REXROTH, G. Air conditioning and ventilating equipment in the hospital. Krankenhaus Umschau, 44(3): 141-144, March 1975.

230. RILEY, R. L. and E. KAUFMAN. Air disinfection in corridors by upper air irradiation with ultraviolet. Architecture Environmental Health, 22: 551-553, May 1971,

231. RILEY, R., L. S. PERMUTT and V. E. KAUFMAN. Correction, air mixing, and ultraviolet air disinfection in rooms. Architecture Environmental Health, 22: 200-207, February 1971.

232. RILEY, R. L. The ecology of indoor atmospheres: airborne infection in hospitals. Journal of Chronic Diseases, 25: 421-423, 1972.

233. RILEY, R. L. and S. PERMUTT. Room air disinfection by ultraviolet irradiation of upper air-air mixing and germicidal effectiveness. Architecture Environmental Health. 22: 208-219, February 1971.

234. RILEY, R. L., S. PERMUTT, and V. E. KAUFMAN. Room air disinfectin by ultraviolet irradiation of upper air: further analysis of corrective air exchange. Architecture Environmental Health, 23: 35-39, July 1971.

235. RITTER, M. A., M. L. V. FRENCH and J. B. HART. Microbiological studies in a horizontal wall-less laminar airflow operating room during actual surgery. Clinical Orthopedic, 97: 16-18, 1973.

236. RITTER, M. A. A system analysis approach to postoperative wound infection. Phase I: Evaluation of a horizontal wall-less laminar air flow system. Cleveland Clinic Quarterly, 40(4): 211-219, 1973.

237. ROEDLER, F. Hospital air conditioning installations and hospital infections. Bundesgesundheitsblatt, 17(1): 1-8, January 1974.

238. ROSE, H. D. Mechanical control of hospital ventilation and Aspergillus infections. American Review of Respiratory Disease, 105(2): 306-307, February 1972.

239. ROSSENSTEIN, S. and P. P. LAMY. Effect of station design on vertical laminar air flow. American Journal of Hospital Pharmacists, 30(9): 800-804, September 1973.

240. RUBBO, S. D., B. C. STRATFORD and S. DIXSON. Spread of a marker organism in a hospital ward. British Medical Journal,282-287, 1962.

241. RUEDEN, H. and K. BOTZENHART. Experimental studies on the capacity of glass-fiber Hepa filters to retain microorganisms. Zentralbl Bakteriol Parasitenkd Infektionskr Hyg Erste Abt Orig Reihe B Hyg Praev Med, 159(3): 284-290, 1974.

242. RUSSENBERGER, H. J. Airborne bacteria counts in operating theatres with various ventilating systems. Zeitschrift fur Praventivmedizin, 17(4): 217-218, July/August 1972.

243. SANDO, F. A. Asepsis, not comfort, is goal of hospital air conditioning. Modern Hospital, 110: 139-142, 1968.

244. SAYER, W. J., N. M. MacKNIGHT and H. W. WILSON. Hospital airborne bacteria as estimated by the Andersen Sampler versus the gravity settling culture plate. American Journal of Clinical Pathology, 58: 558, 1972.

245. SCHARNER, W. and R. SCHNABEL. Patient monitoring : a part of the systems approach to intensive care in the German Democratic Republic. Medical Biological Engineering, 11(4): 390-395, July 1973.

246. SCHEINGRABER, K. Air conditioning in operating theatres. Krankenhaus Umschau, 34(7): 271-274, July 1965.

247. SCHICHT, H. H. and W. STEINER. Air conditioning and environmental sepsis in hospitals and operating rooms. Gesundheitz-Ing, 94(4): 106-114, April 1973.

248. SCHONHOLTZ, G. J. Maintenance of aseptic barriers in the conventional operating room: general principles. Journal of Bone and Joint Surgery, 58-A(4): 439-445, June 1976.

249. SCHULTZ, H. Air hygiene in hospitals. Sanitar-und Heizungstechnik, 33(6): 341-346, June 1968.

250. SCHWAN, A., S. BENGTSSON, A. HAMBRAEUS and G. LAURELL. Airborne contamination and postoperative infection after total hip replacement. Acta Orthop Scand, 48: 86-94, 1977.

251. SCOTT, C.C., J. T. SANDERSON, and T. D. GUTHRIE. Choice of ventilation system for operating-theatres. Comparison of turbulent versus laminar/linear flow systems in operating-rooms and industrial clean rooms. Lancet, 1(712): 1288-1291, June 1971.

252. SCOTT, C. C. and T. D. GUTHRIE. Environmental tests of linear flow ventilation for an operating theatre. British Journal of Surgery. 62(6): 462-467, June 1975.

253. SCOTT, C. C. Laminar/linear flow system of ventilation: its application to medicine and surgery. Lancet, 1: 989-993, May 1970.

254. SCOTT, C. C. The linear flow ventilation system in the theatre. NAT News, 10(4): 6-7, 9-12, 14-15, September 1973.

255. SCOTT, C. C. Letter: Operating-theatre ventilation. Lancet, 1(656): 1121, May 1970.

256. SELL, J. C. Mechanical needs in the operating and delivery suites. Hospitals, 48(21): 79, 82, 84, 150, November 1974.

257. SEROPIAN, R. and B. M. REYNOLDS. The importance of airborne contamination as a factor in postoperative wound infection. Archives of Surgery, 98: 654, 1969.

258. SHAFFER, J. G. Airborne staphylococcus aureus. Archives of Environmental Health, 5: 547-551, 1962.

259. SHAFFER, J. G., D. MIGIT and I. KEY. The microbiological profile of two hospitals of differing structures. Hospitals, 39(18): 71-77, 176, September 1965.

260. SHAW, D., C. M. DIRG and D. DOUGLAS. Is airborne infection in operating theatres an important cause of wound infection in general surgery. Bulletin Society International Chir, 33: 35, 1974.

261. SIEBBELES, H. W. R. Sources of postoperative wound infections with Staphylococcus aureus. Archivum Chirurgicum Neerlandicum, 23: 35, 1971.

262. SKIBA, H. Air conditioning of operating theatres using clean room techniques. Sanitarund Heizungstechnik, 40(2): 19-24; 40(2): 66-72, 1975.

263. SKIDMORE, R. A. Experimental system for the control of surgically induced infections. Human Factors, 17(2): 132-138, April 1975.

264. SMITH, L. R., J. T. NORTON and M. N. JENSEN. Eight years experience using an aseptic air system in surgery. International Surgery, 52(2): 135-140, August 1969.

265. SOHEILI, M. and M. I. PLANT. Air treatment for surgical suites. Hospital Engineering, 27(8): 10-14, November 1977.

266. SOLBERG, C. O. et al. Laminar airflow protection in bone marrow transplantation. Journal of Applied Microbiology, 21(2): 209-216, February 1971.

267. SOLTIS, C. Construction and use of laminar flow rooms. Bulletin of the Parenteral Drug Association. 21(2): 55-62, March/April 1967.

268. Special air systems for operating rooms. American College of Surgeons Bulletin. 57: 18, May 1972.

269. STEFFEN, J. and H. A. SCHULTZE. Air conditioned isolation room for intensive care. Krankenhaus Umschau, 43(3): 210, 212, 213, March 1974.

270. Symposium on operating room environment, Barcelona, September 26, 1973. Bulletin de la Societe Internationale de Chirurgie, 33(1): 1-66, January/February 1974.

271. THOMAS, M.E.M. E. PIPER and I. M. MAUSER. Contamination of an operating theater by gram negative bacteria. Examination of water supplies, cleaning methods and wound infections. Journal of Hygiene, 70: 63-73, 1972.

272. THOMSEN, V. F., S. O. LARSEN and O. B. JEPSEN. Postoperative wound sepsis in general surgery. Acta Chir Scandinavia, 136: 251, 1970.

273. TICHY, S. Our experience with controlled hospital microclimate. Cesk Otolarynologie, 14(6): 350-354, December 1965.

274. TOLON, M. and K. BOTZENHART. Tests of the effectiveness of anti-bacterial UV irradiation in hospitals. Das Offentliche Gesundheitswesen, 36(11): 799-806, November 1974.

275. TREXLER, P. C. An isolator system for the maintenance of aseptic techniques. Lancet, 1: 91, 1973.

276. TURNER, A. G. and J. G. CRADDOCK. Klebsilla in a thoracic ICU. Hospitals, 47: 79, 1973.

277. ULRICH, J. A., W. CRIBBS and G. S. MICHAELSEN. Recirculation of air in operating rooms. ASHRAE Journal, 16(8): 56-61, August 1974.

278. ULRICH, J. A., W. CRIBBS and G. S. MICHAELSEN. Recirculation of air in operating rooms. Medical Instruments, 10(6): 282-286, November/December 1976.

279. Use of laminar air flow in operating rooms suites, topic of NASA-Sponsored symposium.- Hospital Topics, 49: 81+, October 1971.

280. Use of laminar-flow work bench in the operating theatre reduces dust concentration within 15 minutes to one percent. Technische Gids voor Ziekenhuis en Instelling, 39(937): 64, January 1970.

281. Van der MEER, W. J. The need to implement energy conservation insulation standards based on average energy use rather than peak energy use--The New Mexico Experience. Division of Energy Conservative Design, University of New Mexico, Albuquerque, New Mexico.

282. VanDer, WAAIJ, D. Bacteriological aspects of operating theatre ventilation systems. Ziekenhuis, 2(6): 314-319, June 1972.

283. Ventilation in Operation Suites: Joint Working Party on Ventilation in Operation Suites. Department of Health and Social Security, 4: 11, 1972

284. VESLEY, D., A. K. PRYOR and D. E. BATTLES. Minnesota test finds sterile OR cuts infection death rate in half. Modern Hospital, 107(4): 106+, 1966.

285. VIESSMANN, W. Providing the best environment for the hospital surgical suite. Heating, Piping and Air Conditioning, 49: 61-65, August 1968.

286. VINCENT, M. Air conditioning in operating suites. Chauffage, Ventilation, Conditionnement, 44(7): 19-26, 40-41, 43-46, August/September 1968.

287. VIVOLI, G. and L. RENZULLI. Studies of the microclimate and bacterial content of the air in the air conditioned operating rooms and wards of the new polioclinic in Modena. Riv. Ital. Ig., 26: 587-606, September/December 1966.

288. VODA, A. M. and J. H. WITHERS. Laminar airflow in the OR. American Journal of Nursing, 66(11): 2454-2455, November 1966.

289. VOLKSCH, G. The climate in operating rooms and its effect on the hygienic properties of the air. Angewandte Meteoral, 5(9-11): 340-346, 1968.

290. WADSTEN, L. G. Air conditioning in operating theatres. V.V.S., 36(4): 205-209, April 1965.

291. WALTER, C. W. and R. B. KUNDSIN. The airborne component of wound contamination and infection. Archives of Surgery, 107(4): 588-595, October 1973.

292. WALTER, C. W. Three reasons for air conditioning the OR. Hospital Topics, 43: 124, March 1965.

293. WALTER, C. W. Ventilation and air conditioning as bacteriologic engineering. Anesthesiology, 31(2): 186-192, August 1969.

294. WANNER, H. U. Content of bacteria in the air of operating rooms depending on methods of ventilation. Immunitaet und Infektion, 2: 118-122, March 1974.

295. WEBER, M. A. Application of laminar flow design principles in the hospital surgical suite. ASHRAE Transactions, 82(1): 229-243, 1976.

296. WEHRLE, P. F., J. POSCH, K. H. RICHTER and D. A. HENDERSON. An airborne outbreak of smallpox in a German hospital and its significance with respect to other recent outbreaks in Europe. WHO, 43: 669, 1970.

297. WEINSTEIN, R. A. The design of pressure monitoring devices: infection control considerations. Medical Instrumentation, 10: 287-290, 1976.

298. WENZEL, R. P., K. J. HUNTING, C. A. OSTERMAN and M. A. SANDE. Providencia stuartii a hospital pathogen: Potential factors for its emergence and transmission. American Journal of Epidemiology, 104: 170, 1976.

299. WHITBOURNE, J. and K. WEST. Sterility testing. How appropriate for the hospital. Medical Instrumentation, 10: 291-292, 1976.

300. WHITCOMB, J. G. and W.E. CLAPPER. Utraclean operating room. American Journal of Surgery, 112(5): 681-685, November 1966.

301. WHYTE, W. Bacteriological aspects of air conditioning plants. Journal of Hygiene, 66(4): 567-584, December 1968.

302. WHYTE, W.B., B.H. Shaw and J.E. Eakin.A bacteriological evaluation of laminar flow sytems for orthopaedic surgery. Journal of Hygiene, 71: 559-564, 1973.

303. WHYTE, W., J. G. R. HOWIE and J. E. EAKIN. Bacteriological observations in a mechanically ventilated experimental ward and in two open-plan wards. Journal of Medical Microbiology, 2(3): 335-345, August 1969.

304. WHYTE, W. and B. H. SHAW. Comparison of ventilation systems in operating rooms. Bull dela Soc. Int Chir, 33: 42-52, January/ February 1974.

305. WHYTE, W. and B. H. SHAW. The effect of obstructions and thermals in laminar-flow systems. Journal of Hygiene, 72(3): 415-423, June 1974.

306. WHYTE, W., B. H. SHAW and M. A. FREEMAN. An evaluation of a partial walled laminar-flow operating room. Journal of Hygiene, 73(1): 61-74, August 1974.

307. WHYTE, W. and B. H. SHAW. Experimental down/cross flow operating room. Contamination Control Biomedical Environment, pg, 6-9, 13, November/December 1971.

308. WHYTE, W. and W. CARSON. Operating theatre ventilation. Lancet, 1(657): 1179, May 1970.

309. WHYTE, W. and P. ROBERTSON. Some observations on air conditioning in hospitals with special regard to recirculation of the air. IHVE Journal, 38: 150-156, October 1970.

310. WHYTE, W., D. VESLEY and R. HODGSON. Bacterial dispersion in relation to operating room clothing. Journal of Hygiene, 76: 367-378, 1976.

311. WILLIAMS, R. E.O. Epidemiology of airborne staphylococcal infection. Bacteriological Reviews, 30(3): 660-677, 1966.

312. YATES, G. and G. P. BODEY, Laminar air for cancer patients. Contamination Control, 7(10): 20-24, 26, October 1968.

313. ZEISE, D. Requirements in air conditioning system at hospitals for smallpox. 96(11): 306-312, 317, November 1975.

314. ZETTERBERG, H. and R. FULTON. Operating theatres-a change of air. Modern Refrigeration and Air Conditioning, 71(839): 48, 50, 51, February 1968.

315. ZETERBERG, J. M. A review of respiratory urology and the spread of virulent and possibly antigenic viruses via air conditioning systems. Part I and Part II. Annals of Allergy, 31: 228-234, 291-299, 1973.

316. ANDERSEN, B., B. KORNER and A. H. OSTERGARD. Topical ampicillin against wound infection after colorectal surgery. Annals of Surgery, 176: 129, 1972

317. BARNEBEY, H. L. Activated charcoal for air purification. ASHRAE Transactions, 64: 481, 1958.

318. BERNARD, H. R. and W. R. COLE. Bacterial air contamination and its relation to postoperative sepsis. Annals of Surgery, 156: 12, 1962

319. BLOWERS, R., G. A. MASON, K. WALLACE and M. WALTON. Control of wound infection in a thoracic surgery unit. Lancet, 1: 786, 1955.

320. BRADY, L. P., W. F. ENNEKING.and J. A. FRANCO, The effect of operating room environment on the infection rate after Charnley low friction athroplasty. Journal Bone and Joint Surgery, 57A: 80, 1975.

321. BURKE, J. F. Identification of sources of staphylococci contamination of the surgical wound during operation. Annals of Surgery, 158: 898, 1963.

322. CHANDLER, H. W. The epidemiology of surgical infections. II. Bacterial densities in an operating room area. Gruthrie Clinical Bulletin, 30: 38, 1961.

323. COHEN, L. S., F. R. FEKETY and L. E. CLUFF. Studies of the epidemiology of Staphylococcal infections. Annals of Surgery, 159: 321, 1964.

324. Committee on trauma, Division of Medical Sciences, National Academy of Sciences. National Research Council: Report of an ad hoc committee. Postoperative wound infections. The influence of ultraviolet irradiation of the operating room and of various other factors. Annals of Surgery, 160: 192, August 1964.

325. CONDIE, J. D. and D. J. FERGESON. Experimental wound infections contamination versus surgical technique. Surgery, 50: 367, 1961.

326. DECKER, H. M., L. M. BUCHANAN and L.B. HALL. Air filtration of microbial particles. PHS Publication No. 953, 1962.

327. EFTEKHAN, N. The surgeon and clean air in the operating room. Clinical Orthopedics, 96: 188, 1973.

328. ELEK, S. Experimental Staphylococcal infections in the skin of man. Annals New York Academy Science, 65: 85, 1956 .

329. FAVERO, M. S., J. R. PULEO and J. H. MARSHALL. Comparative levels and types of microbial contamination detected in industrial clean rooms. Applied Microbiology, 18: 539, 1966.

330. GAGE, A. A., D. C. DEAN, G. SCHIMERT and N. MINSLEY. Aspergillus infection after cardiac surgery. Archives of Surgery, 101: 384, 1970.

331. GIRDLESTONE, G. R. Infection of "clean" surgical wounds by the surgeon and from the air: work and ventilation of operating theatre. Lancet, 1: 597, 1951.

332. GOLDNER, J. L. and B. L. ALLEN. Ultraviolet light in orthopedic operating rooms at Duke University. Clinical Orthopedics, 96: 195, 1973.

333. GRUN, L. and N. PITZ. Ultraviolet radiation humidifying units and air ducts of hospital air conditioning systems. Zentralblatt fur Bakteriologie, Parasitenkunde, Infectionskrankheiten und Hygiene. 1. Abteilung Originals Reihe B: Hygiene-Preventive Medizin, 159(1): 50-60, April 1974.

334. HARE, R. and M. RIDLEY. Further studies on the transmission of Staphylococcus aureus. British Medical Journal, 1: 69, 1958.

335. HOWE, C. W. and A. T. MARSTON. A study on sources of postoperative staphylococcal infection. Surgery, Gynecology and Obstetrics, 115: 266, 1962.

336. IRVINE, R., B. L. JOHNSON and H. AMSTUTZ. The relationship of genitourinary tract procedures to deep sepsis in total hip replacements. Surgery, Gynecology and Obstetrics, 139: 701, 1974.

337. NOBLE, W. C., O. M. LIDWELL and D. KINGSTON. The size distribution of airborne particles carrying microorganisms. Journal of Hygiene, 61: 385, 1963.

338. O'RIORDAN, C., J. L. ADLER, and H. H. BANKS. Wound infections on an orthopedic service, American Jouranl of Epidemiology, 95: 442, 1972.

339. RIVERS, R. D. Discussion following Pate article. ASHRAE Transactions, 83: 651, 1977.

340. ROBERTS, D. R. Significance of clean wound cultures. American Surgeon, 31: 153, 1965.

341. ROBERTSON, O. H. Airborne infection. Science, 97: 495, 1943.

342. SHOOTER, R. A., J. D. GRIFFITHS, J. COOK and R. E. O. WILLIAMS. Outbreak of staphylococcal infection in a surgical ward. British Medical Journal, 1: 433, 1957.

343. SHOOTER, R. A. M. A. SMITH, J. D. GRIFFITHS, M.E.A. BROWN, R. E. O. WILLIAMS, J. E. REPPEN and M. P. JEVONS. Spread of staphylococci in surgical ward. British Medical Journal, 1: 607, 1958.

344. SOLBERG, C. O. A study of carriers of Staphylococcus aureus. Acta Med Scandinavia, 178: 436, 1965.

345. SPEERS, R., R. A. SHOOTER, H. GAYA, PATEL, NIRAN JONA and J. H. HEURITT. Contamination of nurses uniforms with Staphylococcus aureus. Lancet, II: 233, 1969.

346. TOLON, M. and K. BOTZENHART. Tests of the effectiveness of anti-bacterial ultraviolet irradiation in hospitals. Das Offentliche Gesund-Heitswesen, 36(11): 799-806, November 1974.

347. TYRRELL, D. A. J. Common colds and related diseases. London: Edward Arnold Publishers, 1965.

348. WALTER, C. W., R. B. KUNDSIN and M. M. BRUBAKER. The incidence of airborne infection during operation. Journal of the American Medical Association, 186: 908, 1963.

349. WARDLE, M. D., J. P. NELSON, P. LaLIME and C. S. DAVIDSON. A surgeon body exhaust, clean air operating room system. Orthopedics Review, 3: 43, 1974 .

350. WELLS, W. F. Airborne infection. II. Droplets and droplet nuclei. American Journal of Hgyiene, 20: 611, 1934.

351. WILLIAMS, R. E. O., M. P. JEVONS, R. A. SHOOTER, C. J. W. HUNTER, J. A. GIRLING, J. D. GRIFFITHS and G. W. TAYLOR. Nasal staphylococci and sepsis in hospital patients. British Medical Journal, 2: 658, 1959.

352. WILLIAMS, R. E. O. Intramural spread of bacteria and viruses in human populations. Annual Review Microbiology, 14: 43, 1960.

353. WILLIAMS, R. E. O., W. C. NOBEL, M. P. JEVONS, O. M. LIDWELL, R. A. SHOOTER, R. G. WHITE, B. T. THOM and G. W. TAYLOR. Isolation for the control of staphylococcal infection in surgical wards. British Medical Journal, 2: 275, 1962.

354. Center for Disease Control: National Nosocomial Infections Study Report, Annual Summary 1975, Atlanta, Georgia. October 1977.

355. CRUSE, J. Some factors determining wound infection. A prospective study of 30,000 wounds. H.C. Polk and H. H. Stone, Editors. Hospital acquired infections in surgery. University Park Press, Baltimore, MD.

356. National Academy of Sciences, National Research Council. Post-operative wound infections: the influence of ultraviolet irradiation of the operating room and of various other factors. Annals of Surgery, 160: 1, 1964.

357. Center for Disease Control: Isolation Techniques in Hospitals. 1st edition. Washington, D.C. Government Printing Office. September 1970.

358. Infection Control in the Hospital. 3rd Edition. Chicago, American Hospital Association. 111, 1974.

359. WENZEL, R.P., J.M. VERZEY, and T.R. TOWNSEND. Role of the inanimate in hospital acquired infections. Infection Control in Health Care Facilities, edited by Kenneth R. Cundy and William Ball, University Park Press, Baltimore, London, Tokyo, 1977.

Chapter 4

CHEMICAL CONTAMINATION OF HOSPITAL AIR

For as long as recognition has been given to the importance of providing hospital patients with clean air, attention has been primarily focused on eliminating biological contaminants and controlling the spread of infection. In the interest of protecting patients from biological agents, however, hospitals have exposed both patients and staff to toxic chemicals. The classic case of such exposure in the name of protection was Joseph Lister's practice of spraying carbolic acid (phenol, TLV 5ppm) when he was operating or changing dressings to reduce the danger of airborne infection, a practice he followed and advocated from 1870 until 1887.[17]

When considering possible chemical contamination of hospital air, distinction must be made between the effect of indoor air quality on patients and on hospital employees. Protection of the health of each population makes specific demands on the hospital ventilation system.

Perhaps the most important consideration for patient 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 civilian population. In fact, existing air quality standards and criteria are all based on the assumption that humans divide each day between two environments, outdoor and indoor. The

only data based on continuous exposure to one indoor air source come from NASA and the U.S. Navy, who have studied the effects on human health of air supplies in spacecraft and submarines, respectively.[38,46] Although results from these studies can provide some useful data on effects of continuous exposure to airborne contaminants, they have not lead to standards that would be applicable to hospitals. The differences between ventilation requirements in a closed cabin and in a hospital, in which air is continuously supplied from the outdoors and between physically fit military personnel and hospital patients, limit the applicability of NASA and naval data to the hospital situation.

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. This could be a particular problem in the case of infants, the elderly or people hospitalized with cardiopulmonary or eye problems.

Finally, air quality standards are for the most part based on eliminating health hazards rather than simply avoiding possible annoyances. In a hospital, in which people with illnesses are presumably being treated to improve and restore their health, it can be argued that air ought to do more than not pose a hazard. That is, the environment should actually be supportive to the patient.

Thus the question of the effect of airborne chemical contaminants on hospital patients is unique, and data gathered for drafting of air quality standards and criteria may not apply. Although the special

circumstances of the hospital patient have been mentioned in passing in the literature as interesting areas for possible studies, serious methodical investigation of the presence and health effects of airborne chemical contamination in hospitals has not been undertaken.

Also lacking in the literature is information on non-occupational exposure limits for many toxic chemicals. Extensive studies have not been conducted on questions like the movement of low levels of chemical contaminants through ventilation systems or the synergistic effects of chemicals, for example. For patient protection, the hospital indoor air environment should be examined to see what the general chemical makeup of indoor air is, what sources of contamination could pose a potential hazard to patient health, what sources might be eliminated, and what sources could be isolated and specially treated to reduce overall ventilation energy requirements.

Protection of employee health requires different ventilation considerations from those needed for patient protection. Hospital employee exposure to chemical contaminants is a fairly typical occupational exposure, occurring in 8-hour increments, with the possibility of acute, accidental exposure, or longterm, low level exposure to toxic agents. The problems can be localized, for example, in laboratories or operating rooms. These problems often are dealt with locally; for example, fume hoods can be used in laboratories in which toxic chemicals are used. Problems also can be more generalized, such as those produced by chemicals used in housekeeping or in construction and maintenance activities in the hospital.

Unlike the situation with indoor air quality and patient health,

the question of the effect of chemical contamination on hospital employees has been examined to some extent in the literature. Three reasons can be cited for this attention. First, in the process of determining dose limits for occupational exposure to toxic chemicals, studies have been generated. Secondly, with the existence of occupational health standards, study design is relatively straight forward. It is necessary to only monitor for a particular substance and compare concentrations found to establish permissible levels. Finally, recognition of the epidemiological significance of acute hospital occupational health problems, such as the rate of spontaneous abortions among female anesthesiologists, has focused attention on a few occupational health questions.

In this chapter, a rough and somewhat arbitrary distinction has been made between indoor air quality considerations for patient and for employee health. Basically, in considering the general air environment within the hospital, it concentrates on the effect of that environment on the patient. Because of the dearth of material on indoor air quality and patient health, data are extrapolated from studies of chemical contamination in a number of types of buildings, not just in hospitals. To cover all problems of occupational health in hospitals would go beyond the scope of this chapter; therefore, it includes review of the literature on occupational exposure to anesthetic gases as a case study of ventilation issues that might have to be considered in recommending changes in hospital ventilation.

INDOOR AIR QUALITY: THE OVERALL HOSPITAL ENVIRONMENT

Unpolluted tropospheric air is in part a dry mixture of permanent gases, consisting of approximately 21 percent oxygen by volume, 78 percent nitrogen, 1 percent argon, 0.03 percent carbon dioxide, plus trace concentrations of other gases, including neon, helium, methane, krypton, nitrous oxide, hydrogen and xenon. In addition, air contains varying amounts of water vapor and small quantities of microscopic and submicroscopic particulate matter. These permanent atmospheric impurities arise from various natural processes such as wind erosion, sea spray evaporation, and volcanic eruption.[6,43]

Polluted air also contains numerous other contaminants that are the byproducts of many areas of human endeavor. One classification for such contaminants is based on the form of the material:

1. Solid particulate matter; i.e., dust, fumes and smoke.
2. Liquid particulate matter; i.e., mists and fogs.
3. Non-particulate vapors and gases.[6]

From a public health perspective air contamination may be classified according to the degree of toxicity and the corresponding dose/response relationships.

Air, being a mixture, is subject to variation in all of its components--variations that may lead to different contamination problems in different circumstances. For example, a major concern with air quality in completely unventilated spaces is the oxygen/carbon dioxide balance. In contrast, hazards in ventilated spaces, such as hospitals are those human-generated contaminants that most

frequently occur in far greater concentrations than their background concentrations. Ventilated spaces have two sources of contamination: air pollutants in the outside fresh air and contaminants arising from sources from within. Internal sources can be further subdivided into contamination given off by building materials (offgassing) and contaminants associated with human activities (cooking or laundering).

It should be noted here that standards for indoor air are a confusing, often contradictory collection of design criteria and maximum permissible limits, based on various criteria and margins of safety. A recent EPA report points out the inconsistency with which standards are applied to indoor environments.[33] Hill-Burton standards, which apply specifically to hospitals and other health care institutions (see Chapter 2), require a certain performance level for ventilation systems, rather than specifically limiting the level of particular contaminants. Occupational Health and Safety Administration and American Conference of Governmental Industrial Hygienist Standards deal with occupational exposure to toxic substances and cannot be counted on to protect the patient, whose exposure conditions differ from the occupational exposure of hospital workers. Thus there is no consensus on the limits for "good" hospital indoor air.

INDOOR-OUTDOOR AIR POLLUTION RELATIONSHIPS

Until recently, ventilation engineers operated under the assumption that outdoor air was clean air; thus, the optimum ventilation system was that with the largest proportion of outdoor air and the smallest proportion of recirculated indoor air. This

assumption had additional force in considering hospital ventilation, for outdoor air can be expected to have a lower concentration of infectious agents and can therefore be important in diluting internal biological contamination levels.

Increased external air pollution has called into question the assumption that outdoor air is cleaner than indoor air. Realization that biological agents are not the only hazardous airborne materials in hospitals has caused additional rethinking about the relative merit of outdoor and indoor air input into the hospital ventilation system.

Impeding such reassessment is the lack of data on relationships between indoor and outdoor air pollution. In a literature review from 1972, Benson, et al. found some tentative relationships.[10] Researchers in the United States, Russia, and Japan have found levels of reactive gases and particulates to be greater outdoors than indoors. Beyond that general agreement, however, too many variables have entered the picture to allow drawing more useful conclusions. Because a multiplicity of factors, including internal activity and contaminant sources, atmospheric conditions and natural ventilation, time, location, building type, and air conditioning and filtration systems, must be considered, it is difficult to suggest how more specific information could be generated. Yocum, et al., who have conducted a long-range study of indoor/outdoor relationship in various types of buildings in Hartford, Connecticut, review the difficulties involved in obtaining samples and controlling for the many variables in these studies.[48]

In a well-designed study, Andersen found that two of the main indicators of outside air pollution were significantly reduced in indoor air.[4] Studying an unoccupied room with closed doors and windows over a 7½ month period, he found that the indoor concentrations of sulfur dioxide and suspended particulates averaged 51 percent and 69 percent of the simultaneous outdoor values with correlation coefficients of 0.52 and 0.83, respectively. The sulfur dioxide reduction was attributed to adsorption on room surfaces, while the suspended particulate reduction resulted from differences between outdoor and indoor sedimentation, diffusion and coagulation processes.

Thompson measured total oxidant levels in a Riverside, California community hospital that utilized a conventional air conditioning design where incoming air was prefiltered, then passed through a high-efficiency filter.[44] Generally, levels were found to be approximately one-half of outdoor concentrations. Ironically, however, it was discovered that the intensive care units had corresponding oxidant levels about two-thirds of that prevailing outside. This higher concentration was attributed to the greater use of outside fresh air,(i.e., a "better" system) in the ICUs.

In one of the few studies examining the relationship of outdoor air pollution and air available to hospital patients, Behrman et al., correlating outdoor carbon monoxide concentrations and hemoglobin oxygen-carrying capacity of healthy newborn infants, found a decrease in the oxygen-carrying capacity correlated "remarkably" well with outside carbon monoxide pollution.[9] The hemoglobin oxygen-carrying capacity was compared for infants exposed to outside carbon monoxide concentration of 5 to 20 ppm with those exposed to concentrations

greater than 20 ppm. For infants up to 24 hours old, a 3.0 percent decreased was measured ($P < 0.025$); for infants 24 to 85 hours old, a further decreased of 2.5 percent ($P < 0.025$) was observed. The point made by this study was not that the carbon monoxide levels were hazardous to the health of the newborns, but that the results showed a strong dose/response relationship, with the "dose" being the outside air pollutant and the "response" occurring in the indoor hospital environment.

In anunpublished study, Paulus has monitored air at intake points for two hospitals in St. Paul, Minnesota. One of the two hospitals is located near a freeway.[41] Although carbon monoxide levels at both locations are below the hazard level, higher levels are found at the hospital near the freeway. Furthermore, peak levels are observed during morning and afternoon rush hour and during periods of air inversions.

None of these studies can be taken as evidence that outdoor air pollution levels pose a general threat to the well-being of hospital patients. What they indicate, however, is that ostensibly clean, "fresh" outdoor air should be examined critically by hospital engineers. Hospitals located in urban areas and near freeways in particular may not be best served by the present practice of using large amounts of outside air for ventilation systems.

INTERNAL SOURCES OF INDOOR AIR CONTAMINATION

Although outdoor air should not be assumed to be clean, contamination brought into the hospital through the air intake is not the largest problem facing the ventilation engineer; sources within the hospital

contribute substantially to the chemical contamination load of the hospital environment.[2] 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. The following discussion is not, therefore, a comprehensive review of contamination problems specific to hospitals, but should be interpreted as indicative of the kinds of problems and potential problems that will have to be considered if major changes in ventilation rates are made.

It is perhaps surprising that many of the possible forms of chemical contamination hazards to patients may come not from the special activities and materials found in the hospital, but from common building materials such as concrete and particle board, or from materials like asbestos, which, although no longer used for insulation, may be released during renovation activities or from tobacco smoke.

Formaldehyde

Formaldehyde, especially as a component of formaldehyde-urea resin, is commonly used as a bonding material in particle board and hardwood plywood and as insulation material. In recent years, it has been found that particle board continuously emits formaldehyde, sometimes to the extent that formaldehyde emissions in the home can exceed limits for occupational exposure.[3] Adverse health effects of low level exposure to formaldehyde are upper respiratory and eye irritation. Although the problem is acknowledged in countries in northern Europe and in the United States, where consumer complaints have become more frequent, the lack of a suitable, inexpensive substitute and the still uncertain toxicological effects of long term exposure to

formaldehyde have made manufacturers unwilling to stop using the substance.

It should be emphasized that formaldehyde offgassing from particle board is not presumed to be a significant problem in American hospitals, since particle board is not used extensively as a construction material. But the experience with formaldehyde brings out two points to consider: 1) the difficulty of replacing some materials even after a problem is seen, 2) the gaps that exist in toxicological data.

Radon

Radon-222 is generally acknowledged to be the main source of airborne background radiation in the indoor environment.[19] Building materials such as brick, stone, and concrete are more likely than wood to emit radon. Surveys of residences in Europe and the United States over the past few decades show varying concentrations of radon based on type of construction material, source of construction materials, and ventilation patterns in the building.[22,24,8] The quantity of radioactive substances in building materials also influences the quantity of air ions present (see below). At present hospital ventilation rates, it is not expected that radon poses a threat to the hospital community; however, radon and other background radiation sources must be kept in mind if an extreme lowering of hospital ventilation rates is contemplated.

Air Ions

During the 1920s the phenomena of air ions began to arouse interest in the biological and medical professions. In the 1950s numerous experiments were carried out in order to determine whether

exposure to ionized air might influence such things in man and animals as reactivity, working capacity, comfort and the like, but without ascertaining any unequivocal evidence.[5]

An ion is an atom or group of atoms that contains an electric charge. Atmospheric air contains ions which are divided into two classes based on mobility: 1) light gas ions, and 2) heavy gas ions. The body of literature reviewed did not deal with heavy gas ions, because it is the light gas ions that are thought to exert an influence on biological systems.

Light gas ions are produced in pairs of one negative and one positive ion. Natural production of ions occurs outdoors from cosmic radiation, radioactive material in the earth's crust, or radioactive substances in the air. Production of ions occurs indoors as well as outdoors. The content of radioactive substances in building materials, the rate of generation of radiation from these substances, as well as the rate of ventilation, are all significant factors in determining indoor air ion concentrations.

Opinions on the influence of air ions on humans, range from no effect to the contention that positive effects of air ions are exerted by the negatively charged particles, while detrimental effects are exerted by the positively charged particles. For example, some researchers contend that negative ionized air produces beneficial effects on asthma and hay fever, affects the blood content of serotonin, influences the concentration span of drivers, and influences the stale versus freshness of the air.[5,29,24]

Ventilation exerts an effect on air ion concentration. If incoming room air is filtered it should have a very low content. The rate of exhaust from a room also determines the air ion content. Koning (1978) has reported that artificial airelectrical pulses increased driving performance and reduced errors in concentration tests.[29] Albrechsten et al (1978) reported on the influence of small atmospheric ions on the airways in patients with bronchial asthma.[1] Lung function was shown to improve somewhat at a significant statistical level. Improvement was recorded during negative and positive ion therapy. This was not a double blind study; accordingly, the results were questioned by the authors.

In contrast to these positive reports regarding the influence of air ions, Dr. Andersen's extensive study on air ions and mucociliary function revealed "that no spatial variation in the ciliary frequency resulted from air ion exposure."[5] The application of an electric field also did not change mucociliary function. Kruegerand and Smith, 1968 (as reported by Andersen) determined that cilia and mucociliary function was enhanced by exposure to negative air ions.[5]

The problem with many of the experiments on air ions is that often when a specific effect has been reported from one laboratory it has been completely impossible to repeat the findings at other laboratories.[24] The supposed positive effects of air ions is documented tenaciously

at best. At the present time there is no real hard documented evidence to define what the air ion concentration in a particular environment should be, and therefore, there is no basis on which to based ventilation requirements.

Mercury

Beginning in the 1950s, recognition of increased used of mercury has caused some concern over the possible toxic effects of higher concentrations of mercury to the general public. One area of concern that is still somewhat in dispute is the mercury used as a fungicide in house paints. Based on laboratory tests on mice, Goldberg and Shapero (1957) concluded that no problem existed.[20] In 1965, Jacobs and Goldwater simulated painting of the interior of a residence and concluded that although mercury was aerosolized, it had no harmful effects on either the painters or the people living in the freshly painted room.[23] Despite these and other similar findings, there is some support for the position that efforts should be made to eliminate mercury from house paints.[26] Foote, for example, found mercury vapor concentrations substantially higher than ambient levels.[18]

Smoking

In recent years, more attention has been given to the effects of smoking on the non-smoker who is in the vicinity of the smoker. Although nonsmokers do not absorb large dosages of nicotine, it has

been found that nonsmokers in a room with smokers are exposed to concentrations of carbon monoxide as high as 80 ppm.[42] Furthermore, particulate matter given off by tobacco smoking can place a burden on the ventilation system.

Researchers have stressed that the amount of carbon monoxide in "normal" situations, that is, in which ventilation is adequate and the proportion of smokers to nonsmokers not excessive, is not harmful to a healthy individual. The levels have been found, however, to cause some stress in people with heart disease.[45]

If care is taken in assigning smoking and nonsmoking areas in hospitals, ventilation requirements may be able to be reduced. It should be kept in mind, however, that smoking causes annoyance even more frequently than it causes health hazards, and the decision must be made to what extent patients are to be protected from such an annoyance.

CLEANING AGENTS AS A SOURCE OF HOSPITAL CONTAMINATION

Even less controlled, perhaps, than the previously mentioned substances are the detergents, disinfectants, cleaning fluids, solvents, and other similar materials used in hospital housekeeping activities. Despite frequent warnings in institutional health literature of the potency of some of these substances, it does not appear that hospital housekeeping staffs are paying much attention to problems like potential synergistic effects of various compounds.[35] By simply reflecting on the freedom with which benzene was once used as a solvent will provide an appreciation for the possible unknown sources of chemical contamination that can exist in the hospital.

OCCUPATIONAL HEALTH CONSIDERATIONS

The problems of offgassing from construction materials and of cleaning agents have been singled out above because such airborne contaminants are as likely to affect patient health as they are to affect employee health. In a different vein, many problems of airborne chemical contamination in hospitals pose a threat mainly for the hospital worker. Laboratory and operating room personnel have been singled out as using particularly hazardous substances; below, the literature on occupational health hazards of anesthetic gases is reviewed as an example of this kind of problem.

Anesthetic Gases

From an occupational health standpoint, the hospital airborne chemical contaminants studied most extensively have been the commonly used inhalation anesthetics, nitrous oxide and halothane, which were introduced, ironically, to alleviate dangers associated with flammable anesthetic gases such as ether. Nitrous oxide and halothane, although different in physical properties, display similar air distribution patterns in the operating room. It is assumed that these patterns are applicable to other inhalation anesthetics.

Animal and epidemiological studies have provided evidence that anesthetic gases pose a number of health hazards including:

1. Increased risk of spontaneous abortion in female operating room personnel;
2. Increased risk of birth defects among offspring of female operating room personnel;
3. Increased risk of cancer;
4. Increased risk of hepatic and renal disease; and

5. Detrimental effects on perceptual, congnitive, and motor skills.[7,14,11,21,40]

In a report on the health of 303 Russian anesthesiologists, an unusually high incidence of headaches, fatigue, irritability, increased incidence of spontaneous abortion, and a high incidence of abnormal pregnancies were reported.[42] In one study, in which exposed female anesthetists were compared to a group of unexposed female pediatricians, an increase in abortions was noted in the exposed women.[13] A similar study in the United Kingdom reported the same result plus a trend toward increased incidence of congenital malformations.[28] In a Michigan study, an increased rate of cancer and birth defects was suggested.[14] The inhalation anesthetics present in the air are the most likely offending agents, although a cause-effect relationship has not been definitively established. Based on information collected from surveying about 50,000 operating room personnel, an ad hoc committee of the American Society of Anesthesiologists concluded that an increase in disease rates is seen in operating room personnel and that exposure to waste anesthetic gases in the operating room provides the most reasonable explanation.[40] NIOSH has made recommendations for the use of anesthetic gases.[15] Table 4.1 summarizes those recommendations.

Waste gas scavenging is a significant factor in obtaining clean air in the operating room. The simplest disposal system makes use of the air conditioning system. Kemi (1973) reported a significant reduction in atmospheric contamination with the use of air conditioning.[27] Langley and Steward (1974) studied different ventilation systems and reported that a turbulent flow ventilation system produced an uneven

spread with the greatest concentrations of halothane in the zone breathed by the standing staff.[30] A downward displacement system produced a more even spread throughout the operating room, but with a significantly reduced maximum level of pollution.

Standard ventilation systems cannot reduce the halothane concentration in the atmosphere to levels recommended by NIOSH.[49] Therefore, many methods to reduce the amount of anesthetic gas have been developed, and depend on the use of specially designed scavenging valves, collecting manifolds, or one-way valves. The most effective can be grouped under three main classifications:

1. Discharge of gases at floor or ceiling level, using either a collecting device or disposal tubing plugged into the exhaust duct. It has been claimed to lower gas levels by 90 percent.[7,34] There are two disadvantages: the level of contamination will rise in a nonventilated room (hardly ever the situation in an operating room, however), and an increasing concentration will occur in rooms with recirculated air unless the disposal tubing enters the duct downstream from the point of recirculation. This is a soluble design problem, although it is expensive to correct.

2. Removal by suction. The vapors and gases are removed by piped suction or water pump.[39] A freestanding electric floor sucker will merely pump the exhaust gases out of the exit ports back into the atmosphere. Disadvantages include the possibility of overloading the piped suction, corrosion of the system by the anesthetic vapors, and cost.

3. Discharge of gases and vapors through a pipe buried in the wall or floor of the operating room. This method was first described by Bullough in 1954.[12] The pipe must discharge outside the building and not into the exit corridor. A one-way system must be utilized to prevent reflux into the operating room of unfiltered air and structural alterations to the building are necessary. This system is especially recommended for new construction.

The literature demonstrates that although it is obviously not possible to prevent all contamination of operating room air by anesthetic gases

and vapors, much can be done with equipment modification, air monitoring programs, and good work practices to limit exposure of operating room personnel.

Table 4.1 Synopsis of NIOSH and HEW Recommendations and Regulations Which Pertain to Waste Anesthetics

Recommended Maximum Concentrations

Nitrous oxide 25 ppm (Time Weighted Average).

Hallogenated agents 0.5 ppm (Time Weighted Average) when used in conjunction with nitrous oxide.

Halogenated agents 2 ppm when used as the only gas anesthetic agent.

Anesthetic delivery systems shall be equipped for scavenging or by other methods which are as effective.

Work Practices

1. Proper operation of the waste gas disposal shall be determined prior to the beginning of anesthetic administration.
2. Face mask to provide as effective seal as possible.
3. Vaporizers shall be filled in a ventilated area.
4. Low pressure leak tests conducted daily.
5. Starting anesthetic gas flow before induction is prohibited.
6. When the breathing circuit is disconnected from patient, flow meters shall be turned off or the Y-piece sealed.
7. The breathing bag shall be emptied into the scavenging system before it is disconnected from the delivery system.

Minimum General Ventilation Exchange Rates

Area Designation	Minimum Air Changes of Outdoor Air Per Hour Supplied to Room	Minimum Total Air Changes Per Hour Supplied to Room
Operating Room	5	25
Delivery Room	5	25
Recovery Room	2	6
Anesthesia Storage	Optional	8

Ventilation systems shall be subject to regular preventative maintenance and cleaning. Ventilation shall be verified by quarterly airflow measurements.

Equipment Maintenance

1. High pressure leak quarterly testing; low pressure leak daily testing.

Medical Surveillance

1. Comprehensive preplacement medical and occupational histories.

2. Preplacement and annual physical examinations.

3. Education program.

4. Abnormal outcome of pregnancies shall be documented and maintained for employment times plus twenty years.

Education Program

1. Employee will be informed on assignment or annually thereafter of the potential health risks of trace anesthetic exposure.

Environmental Monitoring Requirements

1. Supervised by a knowledgeable individual familiar with sampling and monitoring techniques or by a professional industrial hygienist.

2. Representative concentrations.

3. Quarterly basis.

Recordkeeping Requirements

1. Sampling data information, air sampling results and medical records following employee termination shall be kept for at least twenty years.

List compiled by Carlson from references 15 and 40.[49]

POTENTIAL OCCUPATIONAL HAZARD FROM OTHER SOURCES OF AIRBORNE CHEMICAL CONTAMINATION

Throughout the hospital, a wide variety of cleaning solvents, many of which are quite volatile, is used for housekeeping purposes such as removing tar from floors, cleaning oxygen lines and fittings, removing tape from the skin, cleaning typewriter keys, and for copying and duplicating equipment. Solvents include perchloroethylene, toluene, petroleum naptha, methyl chloroform, and xylene. Michaelsen (1957) reports an instance in which a custodial worker was using xylene to wash the floor of a tissue laboratory as a solvent to remove wax accumulation.[35] Air samples showed that the worker, who had complained about general ill health over a several month period, was "exposing himself to a concentration several times greater than the maximum allowable"; i.e., 200 ppm. The current TLV for xylene is 100 ppm.

In the pathology laboratory, large quantities of ethyl alcohol, xylene and 10 percent formaldehyde in alcohol are used in auto-technicons. In one study, air concentration of xylene was found to be 133 ppm, with ethyl alcohol concentrations ranging from 25 to 2500 ppm (1000 ppm TLV) and formaldehyde from 0.8 to 10 ppm (2 ppm TLV).[32] The combination of an ethyl alcohol level of 600 ppm and a formaldehyde level of 2 ppm produced lacrimination and nasal burning.

In histology and cytology laboratories, formaldehyde is used as a sample preservative and toluene as a solvent for mounting media. Staining solutions contain ethyl ether, ethyl alcohol and xylene. In several surveyed hospitals, laboratory personnel were found to be exposed to xylene concentrations in excess of the 100 ppm TLV

for short periods, with frequent complaints of headaches.[36]

In laboratories using mercury in carbon dioxide combining-power determinations, mercury vapor concentrations have found to be well in excess of the 0.05 mg/m^3 (as Hg) TLV. In one laboratory utilizing a fairly new piece of equipment, concentrations were measured at less than 0.0375 mg/m^3; however, in another poorly maintained laboratory, the mercury vapor concentration was found to be 0.2 mg/m^3, four times the current TLV.[32] Small puddles of mercury were found on the floor, counters, equipment, and window sills. After cleanup, the mercury vapor concentration dropped to 0.043 mg/m^3, not far below the TLV. Careless handling of mercury is apparently commonplace. In a survey of 30 hospitals in three western states, spilled mercury was visible in 9 out of the 16 hospitals using mercury.[31]

Studies of this kind show increasing interest in the occupational health aspects of the hospital workplace and indicate a growing awareness that hospitals can present significant hazards to employees. Much work needs to be done to ensure a healthy working environment. Hospital ventilation energy conservation strategies must be constrained by this consideration.

SURVEY OF TOXIC CHEMICALS: UNIVERSITY OF MINNESOTA HOSPITALS

Examination of the literature makes it clear that more research has to be done to develop a clearer picture of chemical use in hospitals, including an inventory of substances, description of uses, and analysis of handling practices. This information would seem to be the minimum that must be collected to assist hospital engineers in designing

ventilation systems to provide as much contamination control as possible, but the literature contains no indication that even the most rudimentary survey of this kind has been conducted. Because of the need for such material, the scope of this investigation of chemical contamination in hospitals was expanded beyond the confines of the existing literature, a preliminary survey of use of toxic chemicals at the University of Minnesota Hospitals was conducted. Following is a summary of principal findings.

It is important to note that the University of Minnesota Hospitals were chosen to survey because they were accessible, not because they were felt to present unusual hazard. Data presented here are used to exemplify the kind of situation that is likely to exist in hospitals, generally not to criticize or indict the one institution studied.

University Hospitals are a collection of health care facilities affiliated with the University of Minnesota Medical School. Total inpatient capacity is 761 beds. Located in Minneapolis (population 434,000) and part of the Twin Cities metropolitan region (population two million), the main hospital building was constructed in 1956-57. Additions and remodeling projects are ongoing.

The hospital has a total area of 416,169 square feet. Breakdown of square footage by functional area can be seen in Table 4.2. The health and safety standards under which the hospital operates include those of the Hill-Burton program, state health department licensing requirements, and the state OSHA program. An operational environmental health and safety department on campus monitors fume hoods, operating

room ventilation systems, and other similar devices within the hospital. Number of persons employed was not available, but the fulltime equivalent for hospital employees was 3123.7. Breakdown of employee fulltime equivalents by functional area is shown in Table 4.2.

Methodology

Representatives from each operational unit were contacted and asked to provide information on their chemical usage history. Unit representatives were not asked to segregate toxic from nontoxic substances in their inventory, as this might have lead to differences in definition of "toxic" from department to department. Instead, items on the inventory were labeled toxic or nontoxic on the basis of NIOSH and ACGIH criteria. Department representatives were also asked to indicate approximate quantities and major uses of each chemical (see Table 4.3).

On the basis of this survey, it was determined that toluene and mercury, because of their toxicity and quantities used, might cause particular potential hazards. Areas where these two substances were used were toured to see how safe the materials were being handled. Findings from these tours were discussed with representatives from the Hospitals Laboratory Safety Services.

Results

Results of the survey are seen in Table 4.4. Possibly the most striking aspect of these results is the number of chemicals used as cleaning agents and by painters, that is, material used in areas of the hospital to which patients could be exposed. The following substances

are listed as cleaning agents used by environmental services and by wall washers, the two groups that do much of the housekeeping work in the hospital: ammonia, ammonium chloride, chlorine, p-dichlorobenzene, ethanoic acid, ethanol, hydrochloric acid, phosphoric acid, 2-propanol, sodium hydroxide, 1,1,1-tricholorethane. Agents used by painters include butane, calcium carbonate, dichloromethane, methanol, methylbenzene, 4-methyl, 2-pentanone, mineral spirits, petroleum naptha, propane, titanium dioxide, turpentine, and zinc sterate. It should be stressed that all of these substances were used in concentrations that met the appropriate occupational health limit; however, as was pointed out earlier, virtually no data exist on the non-occupational exposure to these substances. Furthermore, there is very little information on the synergistic effects of such a variety of substances on human health.

Toluene, with a TLV of 100 ppm (NIOSH), was found to be used extensively in laboratories (132 liters/month). A tour of the laboratories was made to observe how and where toluene was used and how carefully it was being handled. It was found that toluene was used most extensively in the immunology laboratory. It was only used under the fume hood and was transported in an approved manner.

Concern over contamination from airborne mercury (TLV 0.05 mg/m^3, NIOSH) led to a tour of the heart catheterization laboratory because mercury is exposed to the air constantly in the Van Slyke apparatus. This device, which is used once a month, has a history of spills. The spills are cleaned up by Laboratory Safety Services, but the interim between spill and clean-up can run from 20 minutes up to as long as

36 hours. Laboratory Safety Services is equipped with the specialized vacuum cleaner needed to properly clean a spot where mercury has been spilled. The service is not operated in the evenings and on weekends, so a decreased capacity for cleanup exits during these times. In an acute emergency situation, safety personnel are called in to clean up. Minor spills on weekends are isolated and confined and clean up might not occur for 36 hours.

Other sources of mercury contamination are broken thermometers (which can usually be wiped up by personnel on the spot) and sphygmomanometer spills, which are the most common source of spilled mercury. According to Laboratory Safety Services, sizable mercury spills (those requiring special clean-up) occur at the rate of about 20 to 25 a year. Laboratory Safety Services logs all mercury spills and will do a follow-up check on a station where there are three or more spills per year.

Discussion

Results are mixed from this very rudimentary survey. First, it is encouraging to note that no extremely hazardous situation was discovered. Employees, especially those working with highly hazardous chemicals, appeared to be following fairly good work practices. Perhaps less encouraging, however, is the realization that such basic inventories are not conducted on a regular basis. The University of Minnesota Hospitals is a teaching/research institution and has been constructed in stages. This means that laboratories are often tucked into corners near patient areas and that ventilation in some spots may be less than optimal. Because of the inability of

administrators to control these physical characteristics, it would seem that potential problems could be prevented if an effort were made to become aware of what chemicals were being used where.

The variety of substances used in departments not generally considered high risk,and in parts of the hospital not served by special ventilation, also seem to indicate that some monitoring of substances used, especially in patient areas, should be ongoing. Furthermore, it might be possible to determine ways in which the variety of substances could be consolidated.

CONCLUSION

Based on this review of the literature and preliminary chemical contaminant survey, further investigation of toxic chemicals in hospitals is recommended. More information is needed on:

1. Substances being used in hospitals.

2. Effects of patient exposure. Research in this area might concern itself with specialized problems such as differences in inhalation of particulates in walking and sleeping breathing patterns or rate of settling of particulates in hospitals.

3. Offgassing of construction materials commonly used in hospitals.

At this point, lack of solid data in these areas makes it difficult to recommend changes in ventilation rates or even to state whether present rates are adequate, insufficient, or overly cautious in dealing with airborne chemical contaminants in hospitals.

Table 4.2 University of Minnesota Floor Space and Staffing

Area Designation	Square Feet	Number of FTE's**
Operating Room	14,919	110
Emergency Operating Room	4,481	26
Delivery Room	3,099	15
Nursery Suite	2,976	62
Recovery Room	5,009	53
Intensive Care	3,575	52
Patient Room	137,752	732
Patient Corridor	*	0
Isolation Room	7,325	53
Isolation Alcove	*	0
Examination Room	*	*
Medication Room	*	*
Pharmacy	5,093	64
Treatment Room	*	*
X-ray, Fluoroscopy Room	13,918	83
X-ray, Treatment Room	5,897	24
Physical Therapy and Hydrotherapy	(See Rehabilitation Center)	
Solied Utility	*	0
Clean Utility	*	0
Autopsy	962	6
Workroom	*	*
Warefrigerated Body Holding Room	*	*
Toilet Room	(See Patient Room)	
Bedpan Room	*	*
Bathroom	*	*
Janitors' Closet	(See Housekeeping)	
Sterilizer Equipment Room	(See (Central Medical & Surgical Supply)	
Linen and Trash Chute Rooms	*	*
Laboratory, General	36,272	384
Laboratory, Media Transfer	(See Laboratory, General	
Food Preparation Centers	9,279	46
Warewashing	(See Food Preparation Centers)	
Dietary Day Storage	4,469	25
Laundry, General	(See Housekeeping)	
Soiled Linen	(See Housekeeping)	
Clean Linen	(See Housekeeping)	
Anesthesia Storage	*	*
Central Medical and Surgical Supply	7,849	45
Soiled Room	(See Central Medical & Surgical Supply)	
Clean Workroom	(See Central Medical & Surgical Supply)	
Unsterile Supply Storage	(See Central Medical & Surgical Supply)	
Housekeeping	17,138	271
Rehabilitation Center	16,286	79

* Data Not Available

** Fulltime Equivelant number of employees

Table 4.3 Chemicals and Quantities used in University of Minnesota Hospital

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)
Ammonia			50 ceiling NIOSH
	Environmental Services - Cleaning Agent	?	
	Morgue - Cleaning Agent	26.50	
	Wall-washer - Cleaning Agent	1.89	
		28.39	
Ammonium Chloride			10 mg/m^3 ACGIH
	Wall-washer - Cleaning Agent	?	
		?	
Benzene*			1 ceiling NIOSH
	Laboratory - Reagent	0.16	
		0.16	
Butane*			600 ACGIH
	Painters - Propellent	0.65	
		0.65	
Butanol* Butyl Alcohol			50 ACGIH
	Laboratory - Reagent	0.47	
		0.47	
Calcium Carbonate			NP ACGIH
	Painters - Paint pigment	28.13	
		28.13	
Chlorine			0.5 ceiling NIOSH
	Material Services - Cleaning Agent	10.41	
		10.41	
p-Dichlorobenzene*			75 ACGIH
	Environmental Services - Defumer	?	
		?	
1,2-Dichloroethane*, Ethylene Chloride			5 NIOSH
	Biomedical Engineering - Solvent	0.04	
	Engineering - Solvent	0.08	
	Laboratory - Reagent	0.95	
		1.07	

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)
Ammonia			50 ceiling NIOSH
	Environmental Services - Cleaning Agent	?	
	Morgue - Cleaning Agent	26.50	
	Wall-washer - Cleaning Agent	1.89	
		28.39	
Ammonium Chloride			10 mg/m^3 ACGIH
	Wall-washer - Cleaning Agent	?	
		?	
Benzene*			1 ceiling NIOSH
	Laboratory - Reagent	0.16	
		0.16	
Butane*			600 ACGIH
	Painters - Propellent	0.65	
		0.65	
Butanol* Butyl Alcohol			50 ACGIH
	Laboratory - Reagent	0.47	
		0.47	
Calcium Carbonate			NP ACGIH
	Painters - Paint pigment	28.13	
		28.13	
Chlorine			0.5 ceiling NIOSH
	Material Services - Cleaning Agent	10.41	
		10.41	
p-Dichlorobenzene*			75 ACGIH
	Environmental Services - Defumer	?	
		?	
1,2-Dichloroethane*, Ethylene Chloride			5 NIOSH
	Biomedical Engineering - Solvent	0.04	
	Engineering - Solvent	0.08	
	Laboratory - Reagent	0.95	
		1.07	

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)
Dichloromethane*, Methylene Chloride			75 NIOSH
	Laboratory - Reagent	0.95	
	Painters - Paint remover	?	
		0.95	
Diethylether*, Ether			400 ACGIH
	Environmental Services - Insecticide	?	
	Laboratory - Reagent	1.97	
		1.97	
Dimethylbenzene*, Xylene			100 NIOSH
	Laboratory - Reagent	73.50	
	Morgue - Mounting slides	0.47	
		73.97	
1,2-Ethandiol*, Ethylene Glycol			100 ACGIH
	Engineering - ?	7.57	
		7.57	
Ethanoic Acid*, Acetic Acid			10 ACGIH
	Laboratory - Cleaning Agent	16.30	
	Material Services - Cleaning Agent	18.12	
		34.42	
Ethanol*, Ethyl Alcohol			1000 ACGIH
	Environmental Services - Cleaning Agent	?	
	Laboratory - Reagent	40.38	
	Morgue - Tissue fixer	29.34	
	Wall-washer - Cleaning Agent	0.06	
		69.78	
Ethyl Ethanoate*, Ethyl Acetate			400 ACGIH
	Laboratory - Reagent	7.02	
		7.02	

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)
Dichloromethane*, Methylene Chloride			75 NIOSH
	Laboratory - Reagent	0.95	
	Painters - Paint remover	?	
		0.95	
Diethylether*, Ether			400 ACGIH
	Environmental Services - Insecticide	?	
	Laboratory - Reagent	1.97	
		1.97	
Dimethylbenzene*, Xylene			100 NIOSH
	Laboratory - Reagent	73.50	
	Morgue - Mounting slides	0.47	
		73.97	
1,2-Ethandiol*, Ethylene Glycol			100 ACGIH
	Engineering - ?	7.57	
		7.57	
Ethanoic Acid*, Acetic Acid			10 ACGIH
	Laboratory - Cleaning Agent	16.30	
	Material Services - Cleaning Agent	18.12	
		34.42	
Ethanol*, Ethyl Alcohol			1000 ACGIH
	Environmental Services - Cleaning Agent	?	
	Laboratory - Reagent	40.38	
	Morgue - Tissue fixer	29.34	
	Wall-washer - Cleaning Agent	0.06	
		69.78	
Ethyl Ethanoate*, Ethyl Acetate			400 ACGIH
	Laboratory - Reagent	7.02	
		7.02	

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)	
Hexane*			100	NIOSH
	Laboratory - Reagent	1.89		
		1.89		
Hydrochloric Acid			5	ACGIH
	Environmental Services - Cleaning Agent	?		
	Laboratory - Reagent	11.67		
		11.67		
Hydrofluoric Acid			6	NIOSH
	Environmental Services - Rust remover	?		
		?		
Hydroxybenzene*, Phenol			5.2	NIOSH
	Laboratory - Reagent	121.80		
		121.80		
Mercury			0.05 mg/m^3	NIOSH
	Laboratory - Process	0.05		
		0.05		
Methanal*, Formaldehyde			1 ceiling	NIOSH
	Laboratory - Tissue fixer	7.44		
	Morgue - Tissue fixer	32.91		
		40.35		
Methanol*, Methyl Alcohol			200	NIOSH
	Laboratory - Reagent	190.43		
	Morgue - Tissue fixer (Formalin)	9.87		
	Painters - Solvent	7.10		
		207.40		
Methylbenzene*, Toluene			100	NIOSH
	Laboratory - Reagent	131.62		
	Painters - Thinner	1.89		
		133.51		

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)	
Hexane*			100	NIOSH
	Laboratory - Reagent	1.89		
		1.89		
Hydrochloric Acid			5	ACGIH
	Environmental Services - Cleaning Agent	?		
	Laboratory - Reagent	11.67		
		11.67		
Hydrofluoric Acid			6	NIOSH
	Environmental Services - Rust remover	?		
		?		
Hydroxybenzene*, Phenol			5.2	NIOSH
	Laboratory - Reagent	121.80		
		121.80		
Mercury			0.05 mg/m^3	NIOSH
	Laboratory - Process	0.05		
		0.05		
Methanal*, Formaldehyde			1 ceiling	NIOSH
	Laboratory - Tissue fixer	7.44		
	Morgue - Tissue fixer	32.91		
		40.35		
Methanol*, Methyl Alcohol			200	NIOSH
	Laboratory - Reagent	190.43		
	Morgue - Tissue fixer (Formalin)	9.87		
	Painters - Solvent	7.10		
		207.40		
Methylbenzene*, Toluene			100	NIOSH
	Laboratory - Reagent	131.62		
	Painters - Thinner	1.89		
		133.51		

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)	
4-Methyl,2-pentanone*, Methyl isobutyl ketone			100	ACGIH
	Painters - Thinner	1.89		
		1.89		
Mineral Spirits, Petroleum Naptha			500	OSHA
	Painters - Thinner	23.45		
		23.45		
Nitric Acid			2	NIOSH
	Laboratory - Reagent	1.07		
		1.07		
Phosphoric Acid			1 mg/m^3	ACGIH
	Environmental Services - Cleaning agent	?		
		?		
Propane*			Asphyxiant	ACGIH
	Engineering - Fuel	?		
	Painters - Propellent	0.65		
		0.65		
Propanol*, Propyl Alcohol			200	ACGIH
	Laboratory - Reagent	3.79		
		3.79		
2-Propanol*, Isopropyl Alcohol			400	NIOSH
	Engineering - Solvent	0.08		
	Environmental Services - Cleaning Agent	0.68		
	Laboratory - Reagent	22.45		
	Material Services - Cleaning agent	6.62		
	Morgue - Cleaning agent	0.06		
	Radiology - Skin disinfectant	16.23		
	Wall-washer - Cleaning agent	0.21		
		46.32		

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)	
4-Methyl,2-pentanone*, Methyl isobutyl ketone			100	ACGIH
	Painters - Thinner	1.89		
		1.89		
Mineral Spirits, Petroleum Naptha			500	OSHA
	Painters - Thinner	23.45		
		23.45		
Nitric Acid			2	NIOSH
	Laboratory - Reagent	1.07		
		1.07		
Phosphoric Acid			1 mg/m^3	ACGIH
	Environmental Services - Cleaning agent	?		
		?		
Propane*			Asphyxiant	ACGIH
	Engineering - Fuel	?		
	Painters - Propellent	0.65		
		0.65		
Propanol*, Propyl Alcohol			200	ACGIH
	Laboratory - Reagent	3.79		
		3.79		
2-Propanol*, Isopropyl Alcohol			400	NIOSH
	Engineering - Solvent	0.08		
	Environmental Services - Cleaning Agent	0.68		
	Laboratory - Reagent	22.45		
	Material Services - Cleaning agent	6.62		
	Morgue - Cleaning agent	0.06		
	Radiology - Skin disinfectant	16.23		
	Wall-washer - Cleaning agent	0.21		
		46.32		

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)	
2-Propanone*, Acetone			1000	ACGIH
	Laboratory - Reagent	26.94		
	Morgue - Tissue fixer	3.31		
		30.25		
Soidum Hydroxide			2 mg/m^3	NIOSH
	Engineering - ?	75.49		
	Environmental Services - Oven Cleaner	?		
		75.49		
Sulfuric Acid			1 mg/m^3	NIOSH
	Engineering - Cleaning Agent	18.93		
	Laboratory - Reagent	9.92		
		28.85		
Tetrahydrofuran			200	ACGIH
	Engineering - PCV cement solvent	?		
		?		
Titanium Dioxide			NP	ACGIH
	Painters - Paint pigment	26.35		
		26.35		
1,1,1-Trichloroethane*			350 ceiling	NIOSH
	Environmental Services - Cleaning agent	3.79		
	Radiology - Degreaser	0.16		
		3.95		
Trichloroethene*, Trichloroethylene			100	NIOSH
	Biomedical Engineering - Solvent	0.16		
	Engineering - ?	11.36		
		11.52		
Trichloromethane*, Chloroform			2 ceiling	NIOSH
	Laboratory - Reagent	57.81		
		57.81		

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)	
2-Propanone*, Acetone			1000	ACGIH
	Laboratory - Reagent	26.94		
	Morgue - Tissue fixer	3.31		
		30.25		
Soidum Hydroxide			2 mg/m^3	NIOSH
	Engineering - ?	75.49		
	Environmental Services - Oven Cleaner	?		
		75.49		
Sulfuric Acid			1 mg/m^3	NIOSH
	Engineering - Cleaning Agent	18.93		
	Laboratory - Reagent	9.92		
		28.85		
Tetrahydrofuran			200	ACGIH
	Engineering - PCV cement solvent	?		
		?		
Titanium Dioxide			NP	ACGIH
	Painters - Paint pigment	26.35		
		26.35		
1,1,1-Trichloroethane*			350 ceiling	NIOSH
	Environmental Services - Cleaning agent	3.79		
	Radiology - Degreaser	0.16		
		3.95		
Trichloroethene*, Trichloroethylene			100	NIOSH
	Biomedical Engineering - Solvent	0.16		
	Engineering - ?	11.36		
		11.52		
Trichloromethane*, Chloroform			2 ceiling	NIOSH
	Laboratory - Reagent	57.81		
		57.81		

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)	
Turpentine	Painters - Solvent	7.57 7.57	100	ACGIH
Vinyl Chloride (Monomer)	Engineering - PVC cement	? ?	1 ceiling	NIOSH
Welding Fumes (Gas & Electric)	Engineering - Welding	? ?	5 mg/m^3	ACGIH
Zinc Sterate	Painters - Paint pigment	0.49 0.49	NP	ACGIH
	TOTAL	1101.08		

* = IUPAC Systematic naming system

NP = Nuisance Particulate

Table 4.3

TOXIC CHEMICAL	WHERE - HOW USED	ESTIMATED LITERS/MONTH	TLV (ppm)
Turpentine	Painters - Solvent	7.57 / 7.57	100 ACGIH
Vinyl Chloride (Monomer)	Engineering - PVC cement	? / ?	1 ceiling NIOSH
Welding Fumes (Gas & Electric)	Engineering - Welding	? / ?	5 mg/m^3 ACGIH
Zinc Sterate	Painters - Paint pigment	0.49 / 0.49	NP ACGIH

* = IUPAC Systematic naming system

NP = Nuisance Particulate

Table 4.4

Chemical Contaminants in Hospitals

Ammonia *

Route of Entry: Inhalation of gas.

Harmful Effects: Causes irritation to the mucous membranes, eyes, and skin.

Ammonium Chloride *

Not listed.

Benzene *

Route of Entry: Inhalation of vapor which may be supplemented by percutaneous absorption.

Harmful Effects: Benzene is suspected to be a human carcinogen, (so deemed by the ACGIH). May produce irritation to the upper respiratory tract, eyes, and skin. Acute exposure results in central nervous system depression.

Butane *

Route of Entry: Inhalation of gas.

Harmful Effects: Natural gas is an asphyxiant.

Butanol *, Butyl Alcohol

Route of Entry: Inhalation of vapor and percutaneous absorption.

Harmful Effects: The vapor is an irritant to the conjunctiva and mucous membranes of the nose and throat, as well as a primary skin irritant.

* IUPAC Naming System

CCH

Calcium Carbonate

Not listed.

Chlorine

Route of Entry: Inhalation of gas.

Harmful Effects: Chlorine reacts with body moisture to form acids. It is itself, extremely irritating to the eyes, skin, and mucous membranes.

p-Dichlorobenzene *

Route of Entry: Inhalation of vapor, and percutaneous absorption of the liquid.

Harmful Effects: Causes irritation to the skin, conjunctiva, and the mucous membranes of the upper respiratory tract. Chronic exposure may result in liver, kidney, and lung damage as indicated by animal experiments.

1, 2-Dichloroethane *, Ethylene Chloride

Route of Entry: Inhalation of vapor and skin absorption of the liquid.

Harmful Effects: May cause eye damage. Inhalation of high concentrations may cause nausea, vomiting, mental confusion, dizziness, and pulmonary edema. Chronic exposure has been associated with kidney and liver damage.

Dichloromethane *, Methylene Chloride

Route of Entry: Inhalation of vapors and percutaneous of the liquid.

Harmful Effects: Irritates the eyes and the upper respiratory tract. It is a mild narcotic and has the same effects as intoxication. Exposure to this agent may cause elevated carboxyhemoglobin levels which may be significant in smokers, or workers with anemia or heart disease, and those exposed to carbon monoxide.

* IUPAC Naming System

CCH

Diethyl ether *, Ether

Route of Entry: Inhalation of vapor

Harmful Effects: The vapor is mildly irritating to the eyes, nose and throat. It has predominantly narcotic properties.

Dimethylbenzene *, Xylene

Route of Entry: Inhalation of vapor, and, to a small extent, percutaneous absorption of liquid.

Harmful Effects: The vapor may cause irritation of the eyes, nose, and throat. Acute exposure to the vapor may cause central nervous system depression.

1, 2-Ethanediol *, Ethylene Glycol

Route of Entry: Inhalation of aprticulate or vapor. Percutaneous absorption may also contribute to intoxication.

Harmful Effects: The vapor pressure of this substance is such that at room temperature, toxic concentrations are unlikely to occur. If heated, poisioning is possible. Inhalation seems to primarily result in central nervous system depression

Ethanoic Acid *, Acetic Acid

Route of Entry: Inhalation of vapor.

Harmful Effects: Respiratory irritant.

Ethanol *, Ethyl Alcohol

Route of Entry: Inhalation of vapor and perctuaneous absorption.

Harmful Effects: Mildly irritating to the eyes and nose. Prolonged exposure may produce headaches, tremors and fatigue.

* IUPAC Naming System

CCH

Ethyl Ethanoate *, Ethyl Acetate

Route of Entry: Inhalation and ingestion.

Harmful Effects: Vapors, high concentrations, irritate the mucous membranes, eyes, and nasal passages. May cause headaches.

Helium

Route of Entry: Inhalation of gas.

Harmful Effects: Helium is an asphyxiant.

Hexane *

Route of Entry: Inhalation of vapor.

Harmful Effects: Irritating to the mucous membranes of the upper respiratory tract. Acute exposure may result in narcosis.

Hydrochloric Acid

Route of Entry: Inhalation of gas or mist.

Harmful Effects: Hydrochloric acid is very corrosive to the eyes, skin, and mucous membranes. The irritant effect of vapors on the respiratory tract may produce laryngitis, glottal edema, bronchitis, pulmonary edema, and death.

Hydroflouric Acid

Route of Entry: Inhalation of gas or mist.

Harmful Effects: Primary irritant of skin, eyes, mucous membranes, and lungs.

Hydroxybenzene *, Phenol

Route of Entry: Inhalation of mist or vapor, percutaneous absorption of mist, vapor, or liquid.

Harmful Effects: Hydroxybenzen has a marked corrosive effect on any tissue. Systemic effects may occur from any route of exposure. These include paleness, weakness, sweating, headache, ringing of the ears, shock,

* IUPAC Naming System

cyanosis, excitement, frothing of the nose and mouth, dark colored urine, and death. If death does not occur, Kidney damage may appear. Repeated or prolonged expsoure to hydroxybenzene may cause chronic hydroxybenzene poisioning.

Mercury

Route of Entry: Inhalation of dust or vapor; percutaneous absorption of elemental mercury.

Harmful Effects: Mercury is a primary irritant of skin and mucous membranes. Acute exposure affects the lungs, primarily in the form of acute interstitial pneumonitis, bronchitis, and bronchiolitis.

Methanal *, Formaldehyde

Route of Entry: Inhalation of gas.

Harmful Effects: The gas may cause severe irritation to the mucous membranes of the respiratory tract and eyes.

Methanol *, Methyl Alcohol

Route of Entry: Inhalation of vapor; percutaneous absorption of liquid.

Harmful Effects: Methanol is virtually non-irritating to the eyes or upper respiratory tract below 2000 ppm. Its toxic effect is thought to be mediated through metabolic oxidation products such as methanal, or methanoic acid.

Methylbenzene *, Toluene

Route of Entry: Inhalation of vapor and percutaneous absorption of liquid.

Harmful Effects: May cause irritation of the eyes, respiratory tract, and skin. Acute exposure usually results in central nervous system depression.

* IUPAC Naming System

4-Methyl, 2-pentanone *, Methyl isobutyl ketone

Route of Entry: Inhalation of vapor and percutaneous absorption.

Harmful Effects: High vapor concentrations may irritate the conjunctiva and mucous membranes of the nose and throat. A narcosis is also produced at high concentrations.

Petroleum Naptha, Mineral Spirits

Route of Entry: Inhalation of vapors.

Harmful Effects: Petroleum naptha irritates the skin, conjunctiva, and the mucous membranes of the upper respiratory tract. May cause depression of the central nervous system.

Nitric Acid

Route of Entry: Inhalation of mist or vapor.

Harmful Effects: May cause necrosis of the skin, mucous membranes, and eye tissues.

Nitrous Oxide

Route of Entry: Inhalation of gas.

Harmful Effects: May produce irritation of the eyes and mucous membranes.

Phosphoric Acid *

Route of Entry: Inhalation of vapors, fumes, or mist.

Harmful Effects: Inhalation of fumes may cause irritation of pulmonary tissues with resultant acute Pulmonary edema. Chronic expsoure may lead to cough, bronchitis, and pneumonia.

Propane *

Route of Entry: Inhalation of gas.

Harmful Effects: Propane is an asphyxiant.

* IUPAC Naming System

Propanol *, Propyl Alcohol

Route of Entry: Inhalation of vapor; percutaneous absorption.

Harmful Effects: The vapors are mildly irritating to the conjunctiva and the mucous membranes of the upper respiratory tract. May also produce mild central nervous system depression.

2-Propanol *, Isopropyl Alcohol

Route of Entry: Inhalation of vapor.

Harmful Effects: The vapors are mildly irritating to the conjuctiva and the mucous membranes of the upper respiratory tract. It is also potentially narcotic in high concentrations.

2-Propanone *, Acetone

Route of Entry: Inhalation of vapor; percutaneous absorption.

Harmful Effects: It is a respiratory irritant, and at high concentrations, may cause headaches, nausea, dizziness, and unconsciousness.

Sodium Hydroxide

Route of Entry: Inhalation of dust or mist.

Harmful Effects: Very corrosive to body tissues. Extreme pulmonary irritation may result from inhalation of dust or mist.

Sulfuric Acid

Route of Entry: Inhalation of mist.

Harmful Effects: It can cause serious injury to mucous membranes and the eyes, but principally the respiratory tract epithelium.

Tetrahydrofuran

Not listed.

* IUPAC Naming System

Titanium Dioxide

Route of Entry: Inhalation of dust or fume.

Harmful Effects: Not highly toxic for man.

1,1,1-Trichloroethane *

Route of Entry: Inhalation of vapor and moderate skin absorption.

Harmful Effects: Irritates the eyes and causes mild conjunctivitis. It acts as a narcotic and depresses the central nervous system.

Trichloroethene *, Trichloroethylene

Route of Entry: Inhalation of vapor; percutaneous absorption.

Harmful Effects: May cause irritation to the eyes, nose, and throat. It also acts as a depressant to the central nervous system after acute exposure.

Trichloromethan *, Chloroform

Route of Entry: Inhalation of vapor.

Harmful Effects: Exposure may lassitude, digetive disturbance, dizziness, mental dullness, and coma. Chronic overexposure has been shown to cause enlargement of the liver and kidney damage. Trichloromethane is considered to be potentially carcinogenic to humans by the ACGIH.

Turpentine

Route of Entry: Inhalation of vapor; percutaneous absorption.

Harmful Effects: High vapor concentrations are irritating to the eyes, nose, and bronchi. In acute concentrations, it may cause central nervous system depression.

* IUPAC Naming System

Vinyl Chloride (monomer)

Route of Entry: Inhalation of gas.

Harmful Effects: Vapor contact with the eyes will cause immediate and severe irritation. Vinyl chloride is regarded as a human carcinogen, and a casual agent of angiosarcoma of the liver.

Welding Fumes

Not listed.

Zinc Sterate

Not listed.

* IUPAC Naming System

References

1. ALBRECHTSEN, O. et al. Influence of small atmospheric ions on the airways in patients with bronchial asthma. Presented at the Indoor Climate Conference, Copenhagen, 1978.

2. ANDERSEN, I. Chemical contaminants: Sources and problems arising therefrom. Paper presented at International Working Conference, Hospital Ventilation Standards and Energy Conservation, Minneapolis, Minnesota. 1978.

3. ANDERSEN, I. et al. Indoor air pollution due to chipboard used as a construction material. Atmospheric Environment, 9: 1121-1127, 1975.

4. ANDERSEN, I. Relationships between outdoor and indoor air pollution. Atmospheric Environment, 6(4): 275-278, 1972.

5. ANDERSEN, I. Mucociliary function in trachea exposed to ionized and non ionized air, Aarhus, Denmark, 1971.

6. ASHRAE Handbook and Product Directory: 1977 Fundamentals. New York: American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1977.

7. ASKROG, V. and B. HARVALT. Results of genetic changes on Danish anesthesia personnel. Nordisk Medicin, 83: 117, 1970.

8. AUXIER, J. A. Respiratory exposure in buildings due to radon progeny. Health Physics, 31: 119-125, 1976.

9. BEHRMAN, R. E., D. E. FISHER and J. PATON. Air pollution in nurseries: correlation with a decrease in oxygen-carrying capacity of hemoglobin. Journal of Pediatrics, 78(6): 1050-1054, 197.

10. BENSON, F. B., J. J. HENDERSON and D. E. CALDWELL. Indoor-outdoor air pollution relationships: A literature review. Publication No. AP 112. Triangle Park, NC: U. S. Environmental Protection Agency, 1972.

11. BRUCE, D. L. and M. J. BACH. Effects of trace anaesthetic gases on behavioural performance of volunteers. British Journal of Anesthesiolia, 48(9): 871-876, 1976.

12. BULLOUGH, J. Anesthetic explosions: prevention by withdrawal method. Lancet, 1: 798, 1954.

13. COHEN E. N. et al. Anesthesia, pregnancy and miscarriage: A study of operating room nurses and anesthetists. Anesthesiology, 35: 343-347, 1971.

14. CORBETT, T. L. Birth defects among children of nurse-anesthetists. Anesthesiology, 41(4): 341-344, 1974.

15. Criteria for a Recommended Standard...Occupational Exposure to Waste Anesthetic Gases and Vapors, HEW Publication No. 77-140, Cincinnati, U. S. Dept. of Health, Education and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1977.

16. DOUGLASS, B. E. Health problems of hospital employees. Journal of Occupational Medicine, 13(12): 1971.

17. FISHER, R. B. Joseph Lister, 1827-1912. New York: Stein and Day, 1977.

18. FOOTE, R. S. Mercury vapor concentrations inside buildings, Science, 177: 513-514, 1972.

19. GESELL, T. F. and H. M. PRICHARD. Measurements of radon-222 in water and indoor airborne radon-222 originating in water. In Radon Workshop, HASL-325, Health and Safety Lab., ERDA, New York, 1977.

20. GOLDBERG, A. A. AND M. SHAPERO. Toxicological hazards of mercurial paints. Journal of Pharmacology, 9: 469-475, 1957.

21. GORSUCH, R. L. AND M. K. KEY. Abnormalities of pregnancy as a function of anxiety and life stress. Psychosomatic Medicine, 36(4): 352-362, 1974.

22. HULTQVIST, B. Studies on naturally occurring ionizing radiations. Kungl. Svenska Vetensk. Akad. Handl. (Stockholm) Serv. 4, 6(3): 1956.

23. JACOBS, M. B. and L. J. GOLDWATER. Absorption and excretion of mercury in man. VIII. Mercury exposure from house paint. Archives of Environmental Health, 11: 582-587, 1965.

24. JONASSEN, N. Static Electricity in Indoor Environments. Paper presented at the Indoor Climate Conference, Copenhagen, 1978.

25. JONASSEN, N. On the effect of atmospheric pressure variations on the radon-222 concentration in unventilated rooms. Health Physics, 29: 216-220, 1975.

26. JOSELOW, M. M. Indoor air pollution by mercury, Ann. Intern. Med., 78(3): 449-450, 1973.

27. KEMI, C. H. Concentrations of halothane in the operating room: The effects of air conditioning. Japanese Journal of Anesthesiology, 22: 1487-1492, 1973.

28. KNILL-JONES, R. P. et al. Anesthetic practice and pregnancy: controlled survey of women anesthetists in the United Kingdom. Lancet, 2: 1326, 1972.

29. KONIG. et al. Subjects in motorcar praxistest influence of air-electrical pulse fields. Presented at the Indoor Climate Conference, Copenhagen, 1978.

30. LANGLEY, D. R. and A. STEWARD. The effect of ventilation system design on air contamination with halothane in operating theatres. British Journal of Anesthesia, 46: 736-741, 1974.

31. LARSON, L. B. and E. J. SELIGMAN. Many hospitals fall short in occupational health programs, sample survey indicates. Hospitals, 43: 75-79, 1969.

32. MAMMEN, H. W. The need for employee health services in hospitals. Archives of Environmental Health, 9: 750-757, December 1964.

33. MCFADDEN, J. E. H. BEARD, III and D. J. MOSCHANDREAS. Survey of indoor air quality health criteria and standards. Report No. EPA-600/7-78-027. Gaithersburg, Maryland: Geomet, Inc. 1978.

34. MEHTA, S. Operating room air pollution: Influence of anesthetic circuit, vapour concentration, gas flow and ventilation. Canadian Anaesthetists Society Journal, 22: 265-274, 1975.

35. MICHAELSEN, G. S. Housekeeping hazards and how to avoid them. The Modern Hospital, 88(1): 134-138, 1957.

36. MILLIKEN, R. A., G. M. MILLIKEN and B. J. MARSHALL. Hospital environmental pollution and employee health hazards. Hospital Topics, 55(2): 22+, 1977.

37. Workers in building say filtered air makes them ill. Minneapolis Tribune, page 4A, August 20, 1978.

38. Compendium of human responses to the aerospace environment, NASA Report No. CR-1205(III), Washington, D. C., 1968.

39. NIKKI, P. Chronic exposure to anesthetic gases in the operating theatre and recovery room. Annals of Clinical Research, 4: 266-272, 1971.

40. Occupational disease among operating room personnel: A national study. Report of an Ad Hoc Committee on the Effects of Trace Anesthetics on the Health of Operating Room Personnel, American Society of Anesthesiologists, Anesthesiology, 41(4): 321-339, 1974.

41. PAULUS, H. J. Carbon monoxide concentrating of intake air at St. Lukes and Miller Hospitals. Unpublished Study. University of Minnesota, Minneapolis, 1977.

42. PORTHEINE, F. To the problem of passive smoking: Remarks to the article by H. P. Harke in Muench Med. Wschr, 112(51): 2328+, 1970. Muench Med. Wschr. (German), 113(18): 707-709, 1971.

43. STERN, A. O. et al. Fundamentals of air pollution, New York: Academic Press, Inc., 1973.

44. THOMPSON, C. R. Measurement of total oxidant levels at Riverside Community Hospital. Archives of Environmental Health, 22: 514-515, 1971.

45. Public exposure to air pollution from tobacco smoke. A Report of the Surgeon General, In: The Health Consequences of Smoking, U. S., DHEW, 1972.

46. Nuclear powered submarine atmosphere control, Report No. NAUSHITS 0938-011-4014, Washington, D. C., 1967.

47. VAISMAN, A. I. Working conditions in surgery and their effect on health of anesthesiologists: A twenty year survey. EKSP. Khir Anest, 3: 44-49, 1967.

48. YOCUM, J. F. and W. A. COTE. Indoor/outdoor air pollutant relationships for air-conditioned buildings. ASHRAE Tranactions, 77(1): 61-71, 1971.

49. CARLSON, K. (Industrial Hygienist) Personal Communication, University of Minnesota Department of Environmental Health and Safety, Minneapolis, Minnesota, 1978.

50. Health hazard evaluation toxicity determination, Report 77-112-447; The hospital for special surgery, New York City, New York. NIOSH, Cincinnatti, Ohio. NTIS Report PB-278 041, 1977.

51. Occupational diseases; a guide to their recognition, DHEW (NIOSH) Publication No. 77-181, Center for Disease Control, Atlanta, Georgia, June 1977.

Chapter 5

THERMAL FACTORS

When evaluating the indoor environment with respect to human health and comfort,four principal thermal factors must be considered: air (dry bulb) temperature; water vapor pressure, usually expressd as relative humidity (RH); air movement, expressed in terms of velocity and direction; and mean radiant temperature. These are independent variables which must be individually controlled by the researcher when investigating human sensory, physiological and pathological responses to the thermal environment.

Current United States hospital ventilation standards (see Chapter 2) specify the thermal environment primarily in terms of dry bulb temperature (°F and/or °C) and relative humidity. In contrast to other types of building space, these standards generally specify tighter temperature and humidity requirements in order to maintain a stable, supportive patient environment. Thus far these standards do not appear to significantly reflect energy conservation measures. For example , in comparing the 1974 Hill-Burton Standards and the Proposed Hill-Burton Standard (Figures 5.1 and 5.2), only a minor relaxation of temperature requirements is evident, while relative humidity requirements are now specified for all inpatient areas.

Since control of temperature and humidity consumes large amounts of energy, this chapter attempts to address patient requirements for temperature and humidity control beyond questions of comfort. In this context, temperature and humidity are considered with respect to their physiological, pathological and microbiological implications.

HILL-BURTON TEMPERATURE AND HUMIDITY STANDARDS

Temperatures and humidities.

(a) The systems shall be designed to provide the following temperatures and humidities in the areas noted:

Area Designation	Temperature		Relative Humidity (%)	
	°F	°C	Min.	Max.
Operating Rooms	70-76*	21-24*	50	60
Delivery Rooms	70-76*	21-24*	50	60
Recovery Rooms	75	24	60	60
Intensive Care Rooms	75-80*	24-27*	30	60
Nurseries Unit	75	24	30	60
Special Care Nursery Unit	75-80*	24-27*	30	60

*Variable Range Required

Figure 5.1
1974 STANDARD

Temperatures and humidities.

(a) The designed capacity of the systems shall provide the following temperatures and humidities in the areas noted:

Area Designation	Temperature		Relative Humidity (%)	
	°F	°C	Min.	Max.
Operating Rooms	68-76*	20-24*	50	60
Delivery Rooms	70-76*	21-24*	50	60
Recovery Rooms	75	24	50	60
Intensive Care Rooms	72-78*	22-26*	30	60
Nurseries Unit	75	24	30	60
Special Care Nursery Unit	75-80*	24-27*	30	60
Other Inpatient Areas	75	24	30	60

*Variable Range Required with individual room control

Figure 5.2
PROPOSED STANDARD

The chapter is introduced with a brief discussion of thermal comfort. There is an extensive amount of literature in this area, and no attempt is made to summarize it herein. Most of the cited research is concerned with sedentary healthy subjects, not with seriously compromised patients. However, an overview is given to provide a baseline for further discussion of temperature and humidity.

It might also be pointed out that considerations other than patient factors also dictate tight temperature and humidity control. For example, NFPA 56A-1973, "Standard for the Use of Inhalation Anesthetics (Flammable and Non-flammable) " (see Chapter 2), specifies:

> *Relative humidity of not less than 50%, at a temperature range of 70° ± 5°F., shall be maintained in anesthetizing locations, both flammable and non-flammable.*

The standard further defines an "anesthetizing location" as

> *Any area of a hospital in which it is intended to administer any flammable or nonflammable inhalation anesthetic agents in the course of examination or treatment, and shall include operating rooms, delivery rooms, emergency rooms, anesthesia rooms, corridors, utility rooms and other areas when for induction of anesthesia with flammable or nonflammable anesthetizing agents.*

Such requirements are acknowledged, but not further discussed.

DEFINITIONS

Marks' Standard Handbook for Mechanical Engineers provides useful temperature and humidity definitions:

The atmosphere is a mixture of air and water vapor. Dalton's law of partial pressures (for the mixture) and the ideal gas law (for each constituent) may safely be assumed to apply. The total pressure B (barometric pressure) is the sum of the vapor pressure p_v and the air pressure p_a.

The temperature of the atmosphere, as indicated by an ordinary thermometer, is the dry-bulb temperature t_d. If the atmosphere is cooled under constant total pressure, the partial pressures remain constant until a temperature is reached at which condensation of vapor begins. This temperature is the dew point t_c (condensation temperature) and is the saturation temperature, or boiling point, corresponding to the actual vapor pressure p_v. If a thermometer bulb is covered with absorbent material, e.g., linen, wet with distilled water and exposed to the atmosphere, evaporation will cool the water and the thermometer bulb to the wet-bulb temperature t_w. This is the temperature given by a psychrometer....The wet-bulb temperature lies between the dry-bulb temperature and the dew point. These three temperatures are distinct except for a saturated atmosphere, for which they are identical. For each of these temperatures, there is a corresponding vapor pressure. The actual vapor pressure p_v corresponds with the dew point t_c. The vapor pressures p_d and p_w, corresponding with t_d and t_w, do not represent pressures actually appearing in the atmosphere but are used in computations.

Relative humidity r is the ratio of the actual vapor pressure to the pressure of saturated vapor at the prevailing dry-bulb temperature $r = p_v/p_d$. Within the limits of usual accuracy, this equals the ratio of actual vapor density to the density of saturated vapor at dry-bulb temperature, $r = \rho_v/\rho_d$. It is to be noted that relative humidity is a property of the vapor alone; it has nothing to do with the fact that the vapor is mixed with air. It is a method of expressing the departure of the vapor from saturation.

It should be noted that p_v is independent of t_c whereas p_d is proportional to t_d. Consequently, for a given partial pressure of water vapor, i.e., water content or absolute humidity, the relative humidity will decrease with increasing dry-bulb temperature. Thus, for a given relative humidity, the water content will increase with increasing dry-bulb temperature.

THERMAL COMFORT

There are many approaches to defining and assessing thermal comfort. Engineers measure the wet and dry bulb temperatures and calculate resultant heat transfer including the effect of clothing; physiologists determine heat balances ; and psychologists evaluate sensations by a variety of scales and take votes of comfort. Clearly,with the multiplicity of factors involved, thermal comfort can be expected to be a subjective value judgment with considerable inter-individual and even intra-individual variability.

From experimental research three mathematical models have evolved to rationally account for the subject's response to his thermal environment: Thermal Sensation (Kansas State University), Predicted Mean Vote (P.O. Fanger), and Pierce Two Node (John B. Pierce Foundation) Models. It is possible with these models to predict the combination of thermal factors (dry bulb temperature, relative humidity, air velocity and mean radiant temperature) which satisfy most people and also to estimate the percentage feeling uncomfortable.[35,39,92] However, nearly all studies have been performed under steady state conditions with a specially selected physically fit population, and it is difficult to generalize these results to apply to other conditions and subjects, particularly to the compromised patient. Most studies performed with college-age subjects and the elderly indicate that the same comfort conditions apply to adults of different ages. This apparently is due to the lower metabolism of the elderly being compensated by a lower evaporative loss.[94]

Those studies that have evaluated human responses to slow unidirectional temperature changes demonstrated that drifts were indistinguishable from the traditionally assumed constant temperature preference.[14,47]

In a 1961 review article, Nevins found the optimum temperature range for thermal comfort to have risen steadily since 1900, from an 18-21 C range to a 24-26 C range in 1960. This increasing trend probably results from the year round use of lighter weight clothing by both men and women and from changing living patterns,including diet and comfort expectations. It is suggested that today, even a 20 C environment may not be wholly acceptable to a significant percentage of individuals. Among contemporary investigators, Legg, 1971, reports 20 C as a standard; Grun, 1974, finds 21-25 C is optimum; Andersen indicates 23.3 C is optimum; and Fanger, 1972, reports 26.1 C as the "comfort maximum." [5,33,48,63]

Relationship of Temperature and Humidity

Rohles and Nevins in their 1971 article, "The Nature of Thermal Comfort for Sedentary Man," described the testing of 800 male and 800 female healthy college students between the ages of 18 and 24. Subjects were exposed in groups of ten, five men and five women, to 20 dry bulb temperatures ranging from 60 F to 98 F in 2 F increments at each of eight relative humidities from 15% to 85% in 10% increments. After one hour and every half hour thereafter, subjects recorded their thermal sensations on a seven category scale ranging from cold to hot. Regression equations were derived from the results and beta values were computed to determine the importance of temperature and humidity in predicting thermal sensation. These results showed that for equal numeric changes (e.g., X F and X% RH), temperature exerts an influence on how men feel almost seven times that of humidity. In contrast, temperature is nine times more important than humidity in determining how women feel.

The body loses heat in three ways: by radiation, by convection and by evaporation. [84,93] At temperatures above 85 F almost all of the

heat loss from the body is by evaporation of perspiration. However, with high humidity, the evaporative process is slowed, causing discomfort. But within the confines of the hospital, assuming 78 F even at 70% RH, no feeling of discomfort should exist. At this temperature most of the heat loss (70%) occurs by convection which depends on the velocity of air movement past the skin. In a hospital with the required air changes occurring per hour in a room, the flow of air past the skin should be enough to provide adequate comfort.

The data shown in the Figure 5.3 below was generated from Rohles and Nevins' work.[93] What is shown is the distribution of slightly cool, comfortable, and slightly warm responses (part of the Rohles Comfort Scale) of men and women after a 3-hour exposure to three relative humidity levels. At a relative humidity in the 65-85% range and 75 F, approximately 90% of the test subjects were comfortable. At 78 F, and the same humidity, 90% of the subjects were also comfortable.

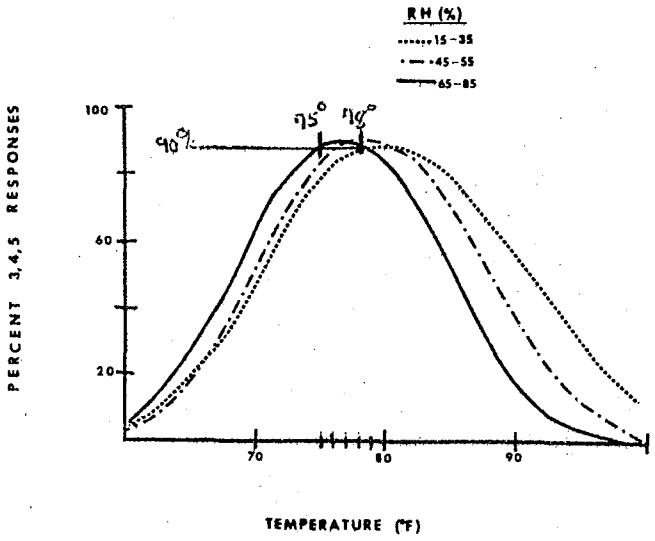


Figure 5.3

This data provides support for allowing temperatures in the summer months to rise above the 75 F requirement specified in the 1974 Hill-Burton Standard, together with a concurrent increase in relative humidity above the 30% - 60% range specified for most of the hospital. This may provide some opportunity for energy conservation.

Whether thermal comfort is also a necessary condition for human health is difficult to assess, and constant thermal conditions particularly, may well not be justifiable in relation to health. Recent directions in thermal comfort research indicate a trend from the concept of optimum to that of thresholds for significant discomfort.[34] This work may well result in defining wider ranges and allowable drifts for both temperature and humidity. For example, the body of research cited above raises an immediate question as to the need for such a tight humidity range in the hospital environment. It clearly cannot be justified solely on the basis of thermal comfort.

If the present hospital thermal standards are necessary, they must be justified on a basis other than thermal comfort criteria developed from investigation of healthy subjects.

The thermal environment in hospitals has to satisfy a variety of people in various stages of activity: patients with minimal activity, nursing staff with activity ranging from light to heavy work, and domestic staff with a heavy workload. Although most patients are well enough to be able to resist or to adapt to moderately unfavorable conditions, this may not be the case with a seriously ill patient or one who is having or has had a serious operation.

The critical ambient temperature for sedentary patients has been considered and assessed by Morris and Wilkey, 1970, and Wyndham,1968, as 21 C .

Body temperatures in rooms cooler than 21 C progressively declined at a mean rate of 0.3 degrees C/hour with light coverings and no movement.[79, 109]

Madsen, 1976, compares the effect of various activities and appropriate insulation levels of clothing for patients and staff members. An increase in clothing from 0 clo (nude) to 1.5 clo (cotton underwear, shirt and pants) will decrease the necessary ambient temperature by 8 C for a sedentary patient and by 19 C for staff at high activity.[73] Certainly much could be done with clothing in hospitals, such as eliminating the open-backed paper gown.

A temperature of 21 C is not adequate for infants and children because their regulatory mechanisms are less effective even with slight temperature variations, and a 24-28 C range is necessary.[85]

These temperatures would, however, be unacceptably warm for the operating room team, as has been shown by Wyon, 1968, and Brock, 1975.[17,110] They find that the temperature most favored by surgeons is 18-21 C , and that earlier recommendations of 27-30 C are obsolete. Full control of patient heat loss by adjustment of the thermal environment in the operating room has not been demonstrated nor is it likely to be practical. Optimum temperatures may be better achieved by direct methods applied to the patient himself. Morris and Trachtenberg, 1968, suggest that warming blankets and warming infused fluids may help decrease patient heat loss.[80]

PHYSIOLOGICAL RESPONSE TO TEMPERATURE

Temperature sensation, physiological strain and health are well summarized in the ASHRAE Handbook and Product Directory, 1977 Fundamentals:

35 C	Hot		Danger of heat stroke
	Warm	Increased blood flow	
30 C	Slightly Warm	Normal regulation by sweating	
25 C	Neutral	Regulation by vascular change	Normal health
20 C	Cool	Urge for more clothing	
15 C	Cold	Shivering	Increasing complaint of dry skin, mucosa
10 C	Very Cold		Muscular pain impaired circulation

Hypothermia

Some current physiological studies suggest that heat loss from ordinary adult patients during surgical operations is significant. Semiclosed and open anesthetic systems contribute to patient heat loss and are commonly used.[70] In addition, long lasting major operations requiring an open body cavity are often done, with large amounts of cold blood transfused into the patient.[15, 42] All these factors contribute to patient heat loss, with varying degrees of intraoperative hypothermia. A reduction in ambient temperature of a few degrees causes a fall in skin temperature, to which the body is able to adjust and readily (compensate by means of peripheral vascular adjustment vasoconstruction). However, postoperative shivering may result in circulatory stress.[12] The relationship has also been studied by Roe, 1966,

who found oxygen consumption increased 92% following intraoperative hypothermia.[91] Other studies report congestion of the lungs, increased blood cell count, and impaired processes of immunity following hypothermia. Nonetheless, mild hypothermia during surgery has not been demonstrated to be harmful. Hypothermia in the newborn, on the other hand, is an important factor jeopardizing neonatal survival, and the metabolic consequences of cold stress (impaired weight gain, increased oxygen consumption, depletion of glycogen stores, etc.) are now well established.[1, 41]

There are those, however, who are working to establish and uphold the principle of the harmfulness of high temperature and great benefits of low temperatures. Cooler temperatures have been recommended for irradiation injury, mechanical traumas, amputations, infections, plastic and orthopedic surgery, and thermal burns.[3]

Elevated Temperatures

Many comprehensive surveys are available on the physiological response to elevated temperatures.[28, 31, 49, 64, 21] At all levels of biological organization, heat presents a stress that brings into play a complex of nervous, endocrine, neurohumoral, and motor functions combining to restore a constant body temperature in the homeothermic animal. These studies associate the incidence of coronary heart disease, hyperthyroid disease and cystic fibrosis with extreme heat conditions. On the other hand, there is little data available in the literature on the effect of more moderate heat stress conditions such as could be encountered in daily life.

Clark and his colleagues, 1954, suggested that above the range of 21 C there is a tendency toward an increased metabolic rate, and that there is a danger of heat retention and hyperpyrexia.[20] Schikele, 1947,

reported fatal cases of hyperthermia occuring as low as 26 C.[100] Other conditions have been reported, including reduction of thyroid activity above 27 C and remission of arthritic swelling and edema. Andersen and his colleagues, 1974, reported that patients with ischemic heart disease are sensitive to moderate heat stress (23-29 C) in terms of mental performance and comfort.[6] Some differences in cardiopulmonary function were noted, but no differences in thermoregulation. Further studies are in progress to test the hypothesis that scar tissue, the end result of either inflammation or injury, is unable to adjust promptly to environmental temperature changes due to decreased vascularization.

HUMIDITY AND HEALTH

In contrast to temperature ,the subject of humidity and its relation to human health is more complex and more controversial. This section examines two components of the issue: host resistance in terms of respiratory functions and chronic disease. The following section discusses humidity as a stress factor on airborne microorganisms.

Upper Respiratory Tract Functions

Air Conditioning. The average male subject inhales 10,000-12,000 liters of air a day. Before air enters the lungs it must travel through the nose or mouth, nasopharnyx, larynx, trachea and finally the bronchi. During this journey the air is cleansed, cooled or warmed, and humidified. This is accomplished by the unique structure of the respiratory tract. The mucosa of the nose, mouth and pharnyx has an extremely large surface area and an extensive vascular system that serves to remove heat from hot air and to heat cold air. In temperate and cold climates, heat and water are transferred from the mucosa to the inspired air. Heat is added by

turbulent convection and water by evaporation.[22] These transfers cool the mucosa. During expiration, some of the water vapor and heat is returned to the mucosa from the alveolar gases. Thus, the respiratory tract conditions inspired air to protect the lungs while at the same time conserving body heat and water vapor by regaining some back during expiration. A subject breathing air at body temperature saturated with water vapor will lose no water or heat. If he breathes very cold dry air he loses both heat and water and may suffer from dehydration of the respiratory tract which could have a deleterious effect because the upper respiratory tract filters air as well as conditions it and moist mucous membranes are necessary for this purpose.

Air Filtration and Cleansing

Air entering the upper respiratory tract is also filtered. Hairs at the inlet block the passage of gross particles, but beyond this area the contour of the nasal passages forces inspired air to pass close to or directly over the nasal mucosa. Larger particles either impinge on the nasal surface or settle out by gravity depending on size. Particles that escape being removed in the nose may impinge on the walls of the nasopharynx and larnynx. Particles between 0.3 and 10 u in diameter may reach the alveolar ducts and alveoli. The filtration mechanism of the upper respiratory tract is important in many respects since it removes foreign particles, dust, bacteria and viruses, and some irritant gases and vapors. Once they have settled on the walls of the nose, pharynx and trachea, particles are removed by sneezing or coughing but mainly by a layer of mucus moved upward by cilia action. Cilia are fine hairlike structures about 10 u long, lining virtually all of the respiratory tract in man. What causes cilia to move is not known, and little is known about

the physiological mechanisms regulating their activity. Cilia beat in strokes; each cilia moving a fast stroke forward followed by a slower stroke backward. There is precise timing among the cilia so that they seem to move in unison in a wavelike pattern. The cilia are covered by the mucous layer, and the effect of the cilia motion is to move this sheet upward to the pharynx where it can be swallowed or expectorated.

Humidity, Mucous Flow and Cilia Action

One of the major supposed influences of relative humidity is its effect on mucous flow and cilia movement in the upper respiratory tract. Some investigators have suggested that the need for extra evaporation of water from nasal mucus during inspiration of dry air decreases cilia activity hence mucus transport, leading to mucostasis in the nasal cavity, and further that cilia drying under extreme low humidity conditions can cause irreversible damage. This is one of the more controversial areas of humidity study and is considered to be one of the major reasons for requiring limitations on humidity. The second major reason for humidity control includes Dunklin and Puck's experiments which showed that staphylococci had the highest death rate at 50% relative humidity as described hereinafter.[29]

Dr. Ib Andersen of the Institute of Hygiene, University of Aarhus, Denmark, is one of the major contributors to studies of the effect of relative humidity on nasal mucosal function, human exposure to dry air and human perception of humidity. Some of his studies are reviewed below.

In his 1972 study, human nasal mucosal flow was measured by tagged particles on 58 healthy subjects. The study was designed to determine under controlled climatic conditions whether an exposure to a very low relative humidity for four hours had a detrimental effect upon nasal

mi.cociliary transport or exposure to a very high relative humidity for eight hours had a beneficial effect. The tagged particle was placed on the superior surface of the interior turbinate. The reason for placement of the particle here was to avoid problems encountered by other investigators. For example, Ewert found a significant relationship between ambient humidity and mucus flow. His technique enabled him to study only a small area of the anterior nasal septum whereas in Dr. Andersen's study the major portion of the nasal passage was examined. In most subjects it was necessary for Ewert to widen the anterior nasal airway, thus affecting the air flow in this important region while Dr. Andersen's procedure did not necessitate this. Each subject in Andersen's study served as his or her own control during the first two hour period where conditions were held constant and mucous flow measured at 70% RH. The reason for 70% RH as the control condition was because this humidity is near the upper range for comfort for indoor conditions, and higher humidities are rarely encountered indoors in the temperature zone. Subjects were then exposed to either 70, 50, 30, or 10% RH at a constant air temperature of 23 C.[4]

Results of this study indicated that a stay of three hours at a relative humidity of 50, 30, or 10% RH had no affect on mucous flow and that an 8 hour stay at 70% RH also did not increase or decrease mucous flow. The airflow was analyzed at maximal voluntary ventilation and an analysis of variance for each nostril, each series of measurements, and each condition, revealed no significant difference existed among the air flows at the four humidity conditions. The findings of this study make it clear that a high ambient humidity does not improve slow mucociliary clearance nor does low ambient humidity impair it.[4]

In 1973, Andersen reported on a study of human perception of humidity.[5] For this research, following acclimation at 70% RH, all subjects were exposed to an unchanged humidity of 70, 50, 30 or 10% RH at a constant 23 C temperature. The subjects were not informed about the experimental conditions, but it was explained that the humidity or temperature might be changed some time during the sessions. Every half hour the subjects were asked to vote about the temperature and humidity in the room on a certain defined scale.

> The main findings were that maximal humidity changes were not perceived as such. The step change in humidity did, however, temporarily alter the subjects' temperature perception. This effect is attributed to humidity absorption and desorption in the clothing causing a transitional heating or cooling effect.

Another major study by Andersen and his associates in 1974 dealt with human response to exposure to dry air. This research was done in response to critics who implied that the 1972 study encompassed such a short time frame so as to preclude humidity from exerting a definite effect on nasal mucosa and respiratory function. In the later research, variables studied included mucous flow rate, nasal resistance, forced vital capacity, skin resistance and discomfort. Eight young, healthy men exposed to clean air at 25 C were studied.

In groups of four, the subjects were indoctrinated as to the procedures to be followed and then confined in the test chamber for a total of 125 hours. To increase the nasal airflow and hence any possible drying effects on the mucous membranes, the subjects pedaled a bicycle ergometer for 20 minutes each day. The first 27 hours were the control period during which the

humidity was held at 50% RH. The humidity was then reduced to 9% RH within one hour and kept at that level for 78 hours when it was again raised to 50% within one hour. [6]

The mucous flow in the nasal cavity was monitored. During the first day at 50% RH, mucous flow decreased but this was not statistically significant. During the dry period, a statistically significant increase in mucous flow was monitored in some parts of the nasal cavity but not in others. Conclusions drawn from the compilation of all data was that contrary to the drying theory, mucous flow increased at 9% RH. During exercise there was a tenfold increase in nasal respiratory flow of dry air and no indication that drying of the mucosa occurred was seen. [6]

A statistically significant decrease in comfort was shown to occur during the dry period. Analysis showed that marked interindividual differences existed, with some noticing the humidity change while others did not. It was concluded that some individuals rated their comfort not on the humidity itself but on the static electricity which became prominent immediately after the humidity was reduced. [6]

Optimum Humidity for Host Resistance.

Sale, 1968, stated that for good health the respiratory mucosa requires a 40 to 50 percent RH. In 1971, he concluded that an "ideal atmosphere" would be one of 40 percent RH at 70 F. [95] Lubart is more consistent. In his two papers published in 1962 he states that 45 percent RH is regarded as optimal. [67,68] Fahnestock and his associates, 1963, stated that 75 F and 45 percent RH is usually required for sedentary workers. [32] Conversely, the aforementioned 1974 study by Andersen and his associates of human response to dry air concluded that there is no physiological need for humidification of air.

Sale believed that during the cold weather human surroundings are excessively heated, inadequately ventilated and completely deficient in proper humidity. He tried to correlate the drying effect on the respiratory membranes with ear, nose and throat problems occurring in the winter. He also stated that dry air thickens the mucous and reduces ciliary motion, causing dry mucous membranes to become more permeable to bacteria and viruses. The problem with all these statements is that they are not backed up by controlled studies.[4,6] Verifying Sale's theory is complicated in that seasonal fluctuation of disease is not only a very general epidemiologic principle, but for a given disease is one of its most constant epidemiologic characteristics. One of the former sweeping applications of the "seasonal prevalence theory" was that upper respiratory tract diseases were all winter disease because of a supposed increase in transmission resulting from winter "crowding." Conversely, a disease not showing similar seasonal prevalence had a different mode of spread. It is a fact that rates of disease vary directly with population density, for example urban and rural differences, but it has not been shown that in any given population seasonal variation follows seasonal "crowding." Seasonal disease prevalence has been attributed to many different things. The host might be more receptive to a disease during the winter due to a multitude of factors. Some of these factors include a decrease in sunlight, physiological changes brought about by changes in temperature, genetic and physiologic differences, pregnancy, and seasonal differences in metabolism. Humidity must also be considered but it cannot be singled out because it is possible that many other variables exert an effect on winter upper respiratory tract infection.[9]

Humidity and Chronic Disease

The literature contains several reports dealing with humidity and its relationship to chronic disease.[53,88,95] Hollander, 1963, and his associates investigated the effect of simultaneous variations of humidity and barometric pressure on arthritis.[53] This study resulted from the observation that increasing humidity and falling barometric pressure almost invariably precede a storm, the time when the arthritic person reportedly feels the worst. Individual variations of climatic parameters had been negative in producing adverse effects on the patient. Humidity at "standard" level was 30% RH and "standard" barometric pressure was 30 inches of mercury absolute. An "obvious and prompt" rise in patient discomfort was noted within four hours of onset of a combined pressure fall and humidity rise. The results obtained when varying multiple parameters led the researchers to conclude that it would "appear that the changing conditions, rather than the high humidity or low barometric pressure, are responsible for adverse effects on the patient." These conclusions lend support to allowing wider humidity ranges in hospitals since the range of humidity in which discomfort was noted is already within the limits required by the Hill-Burton Standard.

Instances where humidity control might possibly be beneficial would include asthma and allergic bronchitis, and other diseases of the respiratory tract. If humidification can be shown to decrease airway resistance a beneficial effect would be exerted for the disease. Sale, 1971,

surveyed 817 of his otologic patients who had used humidifiers to relieve their symptoms for three winters.[95] His concentrated study led him to believe the humidification had a positive effect. Sale believes that dry and heated winter air exert a profound negative impact on his patients respiratory systems. He determined that 65% of his patients had excellent improvement and 30% had good improvement due to humidification. These results can be interpreted to conclude that humidification will alleviate respiratory ailments of patients in the hospital environment. The problem is that Sale made no mention of what the humidity actually was before and after humidification. No controls were used in these experiments, and no mention was made of the remaining 5% of his patients.

In 1935, Rappaport and his associates studied the effect of low relative humidity on pollen asthma.[88] All of their subjects gave a history of attacks of asthma for many years. This study confirmed previous studies that even in pollen free atmospheres, the symptoms of asthma are relieved slowly, leading to the conclusion that some other environmental variable exerts a greater effect on the patients' condition.. A surprising result of this study is that attacks of asthma are precipitated during stormy weather when changing barometric pressures were noticed. This possibly exerts a greater effect on patients than humidity but must be looked at more closely.

In a study by Josenhans, 1969, patients with a known respiratory disorder experienced increasing shortness of breath after a four hour exposure to 92% relative humidity.[59] These results indicated that older patients with respiratory diseases have impaired pulmonary function in atmospheres of high relative humidity. There was no evidence of other persons, without respiratory diseases, experiencing adverse effects on

respiratory function at extreme ranges (10-93%) of relative humidity at room temperature.

These studies, while not showing specific proof, do suggest that variables other than humidity may predominate in causing allergies, asthma, and inflammation in arthritic patients. The literature does not provide definitive guidance as to the effects of humidity on chronic disease patients, but it clearly does not support the current stringent standards.

HUMIDITY AND MICROORGANISMS

Chapter 3 generally discusses the importance of airborne nosocomial infections, in particular exogenous contamination caused by bacteria on squamous cells shed into the air by patients, visitors and staff. This section discusses humidity control as a means of airborne infection control. It considers the susceptibility of pathogenic bacteria and viruses to different humidities and discusses some of the differing opinions as to why and how humidity effects these microorganisms.

As has been previously stated, the 1974 Hill-Burton Standard sets restrictive limits on relative humidities of 50-60% in operating, delivery and recovery rooms and 30-60% in intensive care, nurseries, patient rooms and special care nurseries. Apparently, one of the reasons for confining humidity to these ranges is based on Dunklin and Puck's 1948 article on relative humidity and airborne bacteria which stated that there exist "a narrow range of relative humidity in the vicinity of 50% which is rapidly lethal for microorganisms sprayed into the atmosphere from a broth suspension." [29] Pneumococcus was shown to be the most sensitive at this humidity while streptococcus group C and staphylococcus showed much less sensitivity. It must be remembered that today, Staphylococcus

aureus is responsible for approximately one-sixth of the nosocomial infections but the effect of the humidity on this particular organism is small when compared to that of the pneumococcus. Another point demonstrated by this study is the very narrow range needed to dessicate these microorganisms. Only in the 40-55% RH range is the death rate accelerated, and the 1974 Hill-Burton Standard does not even confine humidity to these limits.

An especially interesting facet of Dunklin and Puck's work is that they tested the effect of relative humidity on bacteria sprayed into the air from a saliva suspension. The survival pattern of microorganisms resulting from these tests mimicked almost exactly that of microorganisms obtained from broth and saliva. This is an important point because the survival of microorganisms generated from different media is of concern when trying to correlate the data to what actually happens when saliva is the medium of atomization.

McDade and Hall, 1964, reported on the effects of relative humidity on surface-exposed gram negative organisms.[74] Their results showed that faster kills of microorganisms occurred at 85% RH than at 53%. A relative humidity of 11% had almost no effect on the survival of Proteus vulgaris.

Kingdon, 1960, reported in his study on relative humidity and airborne infections that the optimum range of humidity necessary for killing airborne viruses lies in the 76%-85% RH range.[61] He used his data to try to develop a hypothesis of a correlation between relative humidity and the onset of the 1957 influenza epidemic. Akers and his associates, 1966, in their work on Columbia SK Group viruses, also showed maximal virus inactivation at greater than 80% RH.[2] Since members of the Col-SK group are picornaviruses, these investigators believe that other small, ether resistant, single stranded RNA viruses will react in the same way.

Cox, 1972, studied the aerosol survival of Pasteurella tularensis twice.[24] His first results showed minimum survival occurred between 50% and 55% RH, but in the second study maximal survival was between 30% and 60% RH, leading him to make the statement that "the reasons for such differences are not clear and indicate that unknown factors influence aerosol survival."

Lester, 1948, determined the influence of relative humidity on infectivity of airborne influenza virus.[65] His results showed that at humidities from 45 to 65% death occurred in 22.5% of mice exposed to an aerosolized suspension of virus, while at 20% or 80% RH, mortality was 100%

Wells has shown that very low humidities are lethal to streptococci Group C atomized into the air. The fault with his data is that he does not specify the exact humidity, simply describing the air as "dehumidified." Benbough has shown that polio virus and T3 phages also have rapid dieoffs at humidities below 50%, with under 10% of the polio virus surviving after one second and under 3% surviving after 5 minutes.[13]

As this review has shown, opinions vary widely on effects of humidity on viruses and microorganisms and some researchers have been unable to duplicate their own experimental results that demonstrated bacterial and viral decay at specific humidities. Each microorganism and virus reacts differently at different humidity levels, and only within narrow limits which are much more restrictive than the Hill-Burton Standard.

Modes of Inactivation of Microorganisms by Humidity

A discussion of the inactivation of microorganisms by humidity must be based on the previously mentioned point that data generated while aerosolizing microorganisms in different media must be used and extrapolated to determine what would actually happen if the organisms were expelled in saliva. Several authors have dealt at length with this problem.[13,29,61,105]

Saliva contains a probable inhibitor with which microorganisms are thought to be associated, as well as sodium chloride in the order of 0.5 mg. per ml.[61] When a droplet leaves the respiratory tract it is leaving an environment of about 100% RH and entering the atmosphere at usually some lower humidity. The droplet immediately starts to lose water by evaporation which progresses until any further size decrease is limited by vapor pressure due to increased concentration of dissolved chemicals or until the solutes in the particle crystallize. The stability of the infective particle within the expelled droplet is directly related to the size of the droplet, the medium containing the microorganism and the humidity of the air which governs the rate of particle shrinkage. The latter point is of most importance since the rate of decay is directly proportional to the rate at which the droplet loses moisture and hence infectivity. At low relative humidities air particles can lose all their water even when in fairly tight chemical combination with the microbial cell. At high relative humidities, even very loosely bound water will remain and at intermediate humidity partial dehydration of the cellular system can occur. Each particular microorganism as shown by the literature cited appears to be influenced by the solute containing the particle at a different humidity. This accounts for the fact that some organisms are resistant at some humidity while others are dessicated. At very low humidities, some cells effectively lysophilized which would protect them while others are dessicated.

Kingdon, 1960, as well as Dunklin and Puck, have established almost conclusively that it is the salt concentration within the expelled cell that exerts the greatest effect on the microbial decay.[29,61] They determined that it was in fact the salts exerting the toxic effect by eliminating certain components of the broth that was used as a suspending medium. All other constituents in the medium when used alone or in combination exerted no lethal effect on the microorganisms.

It has been postulated that at a relative humidity deleterious to the cell, there is a critical degree of moisture content within the cell that renders the vital cellular components most susceptible to toxic agents. Thus, the maximum lethal action of the salt occurs at a relative humidity which dehydrates the microorganism to the point where it becomes most vulnerable. The lethal action of salt at this critical humidity probably involves the inactivation of one or more essential enzyme systems. Death of microorganisms has also been attributed to rapid loss of water movement out of the cell weakening cellular structures, the inactivation of cellular components due to much water in the cell, and the concentration of intracellular materials to toxic levels causing osmotic shocks.[51]

Inactivation of virus has also been shown to be a biphasic event.[29,99,104] The first phase is a rapid initial loss of infectivity sometimes occurring in less than one second, while the final phase is a slower long term inactivation.

CONCLUSION

Many naturally occurring environments such as the Southwestern United States, cold climates and high altitudes all have the common characteristic of dry air, some year round. While all of these areas are dry, none could conceivably approach the 9% RH used by Andersen in his research.[6] The Sahara Desert averages 22%, and any occupied space where people are living and breathing will be maintained at some humidity above 15% RH.

Since the humidity used in the cited experiment was so artificially low and no drying effects on the mucus were seen, in fact the opposite occurred, it can be concluded that in clean air, healthy individuals have no adverse reactions to either low or high humidity. Of course no conclusions can be drawn from these reports about the effects of low humidity on hospitalized patients. The previously mentioned studies by Josenhans do indicate that very high humidity decreases functional residual capacity and hence airway resistance in patients with a pulmonary disease.[59]

Another point shown by this literature review is the differing opinion about the effect of humidity on microorganisms and viruses. Each microorganism and virus reacts differently and only within narrow humidity limits, limits which are more restricted than the Hill-Burton Standard. Consequently, if the standard's tight humidity range is to be justified on the basis of airborne pathogen destruction, a choice must be made as to a specific microorganism or virus.

Overall, one conclusion is that present hospital thermal standards as exemplified by those of the Hill-Burton Program, are extremely conservative and difficult to justify on a basis of available knowledge. At the same time however, there does not appear to be an adequate research base for development of criteria on which a revision of these standards could be based.

A possibility also suggested by this review and particularly attractive from an energy conservation perspective, is a standard based on heating or cooling each room based on the occupants' particular needs, rather than possibly overheating or overcooling the entire complex.

In determining future standards, however, it must be borne in mind that even if mucous and cilia activity, respiratory function and microbial decay do not constrain humidity, other factors may. For example, one area of concern is off-gassing properties of certain building materials. Insulation which is a major building product has been shown to give off formaldehyde in concentrations high enough to be detrimental to health,and humidity seems to exert an influence on the rate of off-gassing. Humidity must also be considered of importance since it has been shown to increase the irritating effects of cigarette smoke and exert a definite effect on the perception of odors. This is a most important consideration when one considers the multitude of cleaning agents, chemicals, odorants, deodorants, etc. used in hospitals. Another major problem is condensation of water vapor on cold surfaces which in turn could cause the growth of allergenic microfungi. A further problem coming to light at the moment is that of mite infestation of the human body by Dermatophagoides, which arevery allergenic. These mites proliferate in indoor dust at humidities above 40%. And finally, there is the problem of shedding skin scales which increase as humidity decreases. It is thought that shedding of epithelial cells is one of the major ways in which microorganisms are transmitted from one person to another during surgery.

References

1. ADAMSON, K. et al. The influence of thermal factors upon O_2 consumption of the newborn infant. Journal of Pediatrics, 66: 495, 1965.

2. AKERS, T. G. et al. Effect of temperature and relative humidity on survival of airborne Columbia Sk group viruses. Applied Microbiology, 14(3): 361-364, May 1966.

3. ALLEN, F. M. Journal of the International College of Surgeons, 15: 201, 1951.

4. ANDERSEN, I. et al. Human nasal mucosal function under four controlled humidities. American Review of Respiratory Diseases, 106: 438-449, 1972.

5. ANDERSEN, I. et al. Human perception of humidity under four controlled conditions. Archives Environmental Health, 26: 22-27, January 1973.

6. ANDERSEN, I. et al. Human response to 78-hour exposure to dry air. Arichives Environmental Health, 29: 319-324, December 1974.

7. ANDERSEN, I. et al. Indoor air pollution due to chipboard used as a construction material. Atmospheric Environment, 9: 1121-1127, 1975.

8. ANSELMI, U. Air conditioning plant for nurseries for premature babies. Nuova Tecnica Ospedaluena, 8(2): 46-50, February 1965.

9. AYCOCK, L. et al. Seasonal prevalence as a principle in epidemiology. American Journal of Medical Sciences, 209(3): 395-411, March 1945.

10. AZER, N. Z. et al. Physiological effects of localized ventilation. Journal of Applied Physiology, 31(5): 669-674, November 1971.

11. BAETJER, A. M. Role of environmental temperature and humidity in susceptibility to disease. Archives Environmental Health, 16: 565-570, April 1968.

12. BAY, J. et al. Factors influencing arterial pressure during recovery from anesthesia. British Journal of Anesthesia, 40: 398, 1968.

13. BENBOUGH, J. E. Some factors affecting the survival of airborne viruses. Journal of General Virology, 10: 209-220, 1971.

14. BERGLUND, L. Mathematical models for predicting the thermal comfort response of building occupants. ASHRAE Transactions, 8 , 1978.

15. BOYAN, C. P. and W. S. HOWLAND. Blood temperature a critical factor in massive transfusions. Anesthesiology, 22: 559, 1961.

16. BREBNER,D. F. et al. The diffusion of water vapour through human skin. Journal of Physiology, 132: 225-231, 1956.

17. BROCK, L. The importance of environmental conditions, especially temperature in the operating room and intensive care ward. British Journal of Surgery, 62(4): 253-258, April 1975.

18. BUGBEE, G. Some questions and answers on the Hill-Burton Act. Hospitals, 21: 42-44, March 1947.

19. Center for Disease Control. National nosocomial infections study report. Annual Summary, 1975. Atlanta, George, Issued October 1977.

20. CLARK, R. E. et al. Body temperature studies in anesthetized man: Effect of environmental temperature, humidity and anesthesia system. Journal of the American Medical Association, 154: 311, 1954.

21. COLLINS, K. J. and J. S. WEINER. Endocrinological aspects of exposure to high environmental temperatures. Physiological Reviews, 48: 785, 1968.

22. COMROE, J. Physiology of respiration. Yearbook Medical Publishers Chicago, 1970

23. CONN, G. D. Temperature and humidity control in a premature baby unit. Hospital Engineer, 19(6): 169-170, June 1965.

24. COX C. S. Aerosol survival of Pasteurella tularensis and the influence of relative humidity. Applied Microbiology, 23(1): 1-3, January 1972.

25. CRAMER, I. Atmospheric moisture content and respiratory mucous membranes. Annals of Allergy, 24: 552-554, October 1966.

26. DeJONG, J. C. and K. C. WINKLER, Survival of measles virus in air. Nature, 201: 1054-1055, March 1964.

27. DeJONG, J. C. The inactivation of poliovirus in aerosols. Journal of Hygiene, 66: 557-565, 1968.

28. DILL, D. B. et al. Handbook of Physiology. Washington D. C.,1964.

29. DUNKLIN, E. W. and T. T. PUCK. The lethal effect of relative humidity on airborne bacteria. Journal of Experimental Medicine, 87: 87-101, February 1948.

30. EDSTROM, G. et al. Investigations into the effect of hot, dry microclimate on peripheral circulation, etc., in arthritic patients. British Medical Association, 6-7: 76-82, 1947-1948.

31. EULER, C. Physiology and pharmacology of temperature regulation. Pharmacy Review, 13: 361, 1961.

32. FAHNESTOCK, M. K. et al. Comfort and physiological responses to work in an environment of 75°F and 45% relative humidity. ASHRAE Transactions, 69: 13-23, February 1963.

33. FANGER, P. O. Calculation of thermal comfort: introduction of a basic comfort equation. ASHRAE Transactions, 73: 1-20, 1967.

34. FANGER, P. O. Future Research needs concerning the human response to indoor environments. ASHRAE Transactions, 84(1): 1978.

35. FANGER, P. O. Thermal comfort. New York: McGraw-Hill Book Company, 1973.

36. FANGER, P. O. Thermal comfort: analysis and application in environmental engineering. New York: McGraw-Hill Book Company, 1972.

37. Full Text of S. 191 as adopted by the United States Senate. Hospitals, 20: 75-79, January 1946.

38. GAGGE, A. P. et al. The effective radiant field and operative temperature necessary for comfort with radiant heating, ASHRAE Journal, 63-65, May 1967.

39. GAGGE, A. P. et al. The role of clothing in meeting FEA energy conservation guidelines. ASHRAE Transactions, 82(2): 234-246, 1976.

40. GELPERIN, A. Humidifications and upper respiratory infection incidences. Heating, Piping & Air Conditioning, 77-78, March 1973.

41. GLASS, L. et al. Effect of thermal environment and cold resistance and growth of small infants after first week of life. Pediatrics, 4: 1033, 1968.

42. GOLDBERG, M. J. and C. F. RAE. Temperature changes during anesthesia and operations. Archives of Surgery, 93: 365, 1966.

43. GOODLOW, R. J. and F. A. LEONARD. Viability and infectivity of microorganisms in experimental airborne infection. Bacteriology Review, 25: 182, 1961.

44. GOROMOSOV, M. S. The physiological basis of health standards for dwellings. Geneva: World Health Organization, 1968.

45. GREEN, G. H. The effect of indoor relative humidity on absenteeism and colds in schools. ASHRAE Journal, 17(1): 57-62, 1975.

46. GRICE, K. et al. The effect of ambient humidity on transepidermal and colds in schools. ASHRAE Journal, 17(1): 57-62, 1975.

47. GRIFFITHS, I. D. AND D. A. McINTYRE. Sensitivity to temporal variations in thermal conditions. Ergonomics, 17: 499, 1974.

48. GRUN, L. Air conditioning from the hygiene point of view. World Hospitals, 10: 24-26, Janaury 1974.

49. HARDY, J. D. Physiology of temperature required. Physiological Reviews, 4: 521-606, 1961.

50. HATCH, M.T. and R. L. DIMMICK. Physiological responses of airborne bacteria to shifts in relative humidity. Bacteriological Reviews, 30(3): 597-603, September 1966.

51. HATCH, M. T. et al. Responses of airborne Mycoplasma pneumaniae to abrupt changes in relative humidity. Applied Microbiology, 19(2): 232-238, February 1970.

52. HEMMES, J. H. et al. Virus survival as a seasonal factor in influenza and poliomyelitis. Nature, 430-431, October 1960.

53. HOLLANDER, J. P. et al. The effect of simultaneous variations of humidity and barometric pressure on arthritis. Bioscience, 13: 24-28, 1963.

54. Hospital Ventilation Standards and Energy Conservation: Proceedings of the 1978 International Working Conference, School of Public Health University of Minnesota, Minneapolis.

55. HOUGHTEN, F. C. et al. Comfort requirements for low humidity air conditioning. ASHUE, 47: 139-158, 1941.

56. HOUGHTEN, F. C. and C. P. YAGLOU. Cooling effect on human beings by various air velocities. ASHRAE Transactions, 30: 193, 1924.

57. HUDENBERG, R. The background of Hill-Burton building standards. Hospitals, 21: 54-55, August 1947.

58. JENSEN, K. et al. Investigation on man's thermal comfort and physiological response. ASHRAE Journal, 47(1): 65-68, January 1971.

59. JOSENHANS, W. T. et al. Effect of humidity in inspired air on air-resistance and functional residual capacity in patients with respiratory disease. Respiration, 26: 435, 1969.

60. KARAN, S. et al. The incidence, clinical profile, morbidity and mortality of hypothermia in the newborn. Indian Pediatrics, 12(12): 1205-1210, December 1975.

61. KINGDON, K. H. Relative humidity and airborne infections. American Review of Respiratory Disease, 81: 504-512, April 1960.

62. LANKE, L. and B. WEDIN. Water evaporation from normal skin under different environmental conditions. Acta Dermatovener, 51: 111-119, 1971.

63. LEGG, R. C. Thermal environment in hospital wards. Hospital Engineering, 25: 87-93, May 1971. 25: 106-109, June 1971.

64. LEITHEAD, C. S. and A. R. LIND. Heat stress and heat disorders. Cassell, 1964.

65. LESTER, W. The influence of relative humidity on the infectivity of airborne influenza A virus (PR 8 Strain). Journal Experimental Medicine, 88: 363-368, 1948.

66. LOOSLI, C. G. et al. Experimental airborne influenza infection. Proceedings Social Experimental Biological Medicine, 53: 205, 1943.

67. LUBART, J. The common cold and humidity inbalance. New York State Journal of Medicine, 816-819, March 1962.

68. LUBART, J. Colds, antibiotics and humidity. Archives of Pediatrics, 223-227, June 1962.

69. LUND, M. Thermal comfort measurements. ASHRAE Transactions, 82(1): 60-75, 1976.

70. MacINTOSH, R. et al. Physics for the Anesthetist, R. A. Davirs, Co., 1963.

71. MACKEY, C. O. Mixtures of air and water vapor. Mark's Standard Handbook for Mechanical Engineers, New York: McGraw Hill Publishing. 1967.

72. MADSEN, T. L. Thermal comfort measurements. ASHRAE Transactions, 82(1): 60-75, 1976.

73. MADSEN, T. L. The ward temperature. Tidsskrift for Danske Sygehus. 52: 82-85, May 1976.

74. McDADE, J. J. and C. B. HALL. Survival of gram-negative bacteria in the environment. I. Effect of relative humidity on surface-exposed organisms. American Journal of Hygiene, 80: 192-204, 1964.

75. McINTYRE, D. Three approaches to thermal comfort. ASHRAE Transactions, 84(1): 1978.

76. McNALL, P. E. and R. G. NEVINS. A critique of ASHRAE comfort standard, 55-66. ASHRAE Journal, 10: 99-102, 1968.

77. MELVILLE, G. N. et al. Changes in specific airway resistance during prolonged breathing of moist air. Canadian Journal of Physiology and Pharmacology, 48: 592, 1970.

78. Minimum requirements of contruction and equipment for hospital and medical facilities. Department of Health, Education and Welfare Pub. No. (HRA) 74-4000. Hill-Burton, 1974.

79. MORRIS, R. H. and B. R. WILKEY. The effects of ambient temperature on patient temperature during surgery not involving body cavities. Anesthesiology, 32(2): 102-107, February 1970.

80. MORRIS, R. H. and H. A. TRACHTENBERG. Physiological alterations induced by blood warming during light ether anesthesia. Anesthesiology 29: 205, 1968.

81. MUNSON, D. and R. B. HAYTER. An overview of clothing as it relates to the physiology of human comfort. ASHRAE Transactions. 84(1): 1978.

82. NASH, T. Physical aspects of air disinfection. Journal of Hygiene. 49: 382-399, 1951.

83. NEVINS, R. G. Psychometrics and modern comfort. ASHRAE-ASME meeting, November, 1961.

84. NISHI, Y. and K. IBAMOTO. Model skin temperature. An index of thermal sensation in cold, warm and humid environments. ASHRAE Transactions, 75(2): 1969.

85. ORDOGH, I. Scientific and technical problems of air conditioning for the environment of premature infants. Industries Thermiques et Aerauliques, 15(590): 33-36, January 1969.

86. Physiological principles, comfort and health. ASHRAE Handbock of Fundamentals, 1977

87. PROETZ, A. W. Humidity, a problem in air conditioning.

88. RAPPAPORT, B. et al. The effect of low relative humidity at constant temperature on pollen asthma. The Journal of Allergy, 6(2): 111-122, January 1935.

89. RILEY, R. Airborne infection. The American Sound of Medicine, 57: 466-475, September 1974.

90. ROBINSON, S. et al. Physiologically equivalant conditions of air temperature and humidity.

91. ROE, C. F. et al. The influence of body temperature on early postoperative oxygen consumption. Surgery, 60: 85, 1966.

92. ROHLES, F. H. The measurement and prediction of thermal comfort. ASHRAE Transactions, 80: 98, 1974.

93. ROHLES, F. H. Humidity, human factors and the energy shortage. ASHRAE Transactions, 81(1): 716-720, 1975.

94. ROHLES, R. H. . M. A. JOHNSON. Thermal comfort in the elderly. ASHRAE Transactions, 78: part 1, 1972.

95. SALE, C. S. Reducing upper respiratory tract infections by allergy control and humidity control. Virginia Medical Monthly, 96 : 368-371, July 1969.

96. SALE, C. S. The lethal effect of relative humidity on airborne bacteria and viruses. Virginia Medical Monthly, 98: 19-24, January 1971.

97. SALE, C. S. Humidification to reduce respiratory illness in nursery school children. Southern Medical Journal, 65(7): 882-885, July 1972.

98. SATALOFF, J. and H. MENDUKE. Humidity studies and respiratory infections in a public school. Clinical Pediatrics, 2(3): 119-121, March 1963.

99. SCHAFFER, F. L. et al. Survival of airborne influenza virus: effects of propogating host relative humidity, and composition of spray fluids. Archives of Virology, 51(4): 263-273, 1976.

100. SCHIKELE, E. Military Surgeon, 100: 235, 1947.

101. SELVAAG, J.A. Residential humidification versus energy conservation. ASHRAE Transactions, 81(1): 697-700, 1975.

102. SHAVIT G. Design criteria for energy conservation. ASHRAE Journal, 17(6): June 1975.

103. SHAVIT, G. Humidity control and energy conservation. ASHRAE Transactions, 81(1): 701-715, 1975.

104. SONGER, J. Influence of relative humidity on the survival of some airborne viruses. Applied Microbiology, 15(1): 35-42, January 1967.

105. WEBB, S. J. et al. The effect of relative humidity and inositol on airborne viruses. Canadian Journal of Microbiology, 9: 87-93, 1963.

106. WELLS, W. F. and P. ZOPPASODI. The effect of humidity on B streptococci atomized in air. Science, 96: 277, 1948.

107. WILLIAMSON, A. E. and H. B. GOTASS. Aerosol sterilization of airborne bacteria. Indian Medical Surgery, 11: 40, 1942.

108. WOODS, J. E. Thermal and non-thermal human responses to air movement and relative humidity. ASHRAE Transactions, 84(1): 1978.

109. WYNDHAM, C. H. et al. Reactions to cold. Journal of Applied Physiology, 24: 282, 1968.

110. WYON, D. P. et al. Thermal comfort during surgical operations. Journal of Hygiene, 66: 229-247, 1968.

Chapter 6

ODORS

The sense of smell adds an additional dimension to our environmental stimuli, in combination with sight, touch and taste. People often think of smell as one of our more primitive defensive and offensive mechanisms and imagine ancient man stalking his prey and being led by his nose. Many mammals use odors to delineate their territory, but it is doubtful that man's sense of smell was ever sufficiently developed for this purpose. Human reactions to odors are similar to those of other senses: involuntary and spontaneous; and either liking, disliking or indifferent.[8] Odors are either liked or disliked based upon previous experience with the odor or a similar odor. Pleasant odors conjure up in our minds visions of pleasant things while unpleasant odors can create discomfort. Odors have a significant bearing on human interaction in today's society. Persons are categorized by their odors whether the odor is real or not, and the odor emanating from the individual is used to indicate moral purity, social status and living standards.[29] The entire nervous system is affected by odors.[8] Different odors react to influence our heartbeat, respiration, and other reflexes and calm us or put us on the defensive.

One of the major problems with odors is that the personal likes and dislikes of people and cultural groups cause a particular odor to be classified as pleasant or unpleasant. A given odor that is preferred by a majority can still be disliked by some minority, and

some odors no matter how repulsive to a majority might still appeal to some minority. Such unintentional biases may reduce the validity of investigator's results in sensory testing. Yet any data developed by other than the human nose is not capable of revealing the pleasure/displeasure quality of the odor, nor of reflecting secondary effects caused by interactions. Odorants may not always be recognized as odor producing. For example, air that may be characterized as stale or stuffy is usually contaminated with a conglomeration of occupied space odorants producing a depressing physiological or psychological response rather than the sensation of odors. It is difficult then to set standards and limits for such a subjective concern. It must be recognized that hospital odors are a problem that does cause patient and staff discomfort and that ventilation rates must be considered when dealing with odor control.

Control of odors in occupied spaces becomes more important with the reduction of diffusion by improved building construction, increased outdoor air pollution, increased internal use of processes and materials which release volatile chemicals, and the development of odor controlling methods. There are many sources of odors that cause discomfort to individuals in occupancy areas. In hospitals, the most common obnoxious odors are body odors, tobacco smoke odors, human and animal wastes, and the frequent use of disinfectants.[32] Odors may also be contributed by food, cooking, linoleum, paint, cleaning materials, upholstery, rugs, drapes, and other ward furnishings.

This chapter discusses the physiological aspects of olfaction, odor classification, odor thresholds, odor measurement, ventilation rates and standards, and methods for odor control is related to the problem of odors in the hospital.

PHYSIOLOGICAL ASPECTS

The nose is the most prominent feature of the face, and most people associate the nose with the sense of smell. Actually, the nasal passages continue for about 2½ to 3 inches and join the top of the pharnyx or throat. The olfactory cleft which is the seat of the sense of smell, is located in the region behind and just below the eyes. The inside of the nostrils is lined with a delicate continuation of the epithelium that lines the outside of the nose. The mucosa of the nose, in combination with the mouth and pharynx,has an extremely large surfacearea and an extensive vascular system that serves to remove heat from hot air and to heat cold air. Air entering the nose is also filtered. Hairs at the inlet block the passage of large particles, and beyond this area the contour of the nasal passage forces inspired air to pass close to or directly over the nasal mucosa. Larger particles either impinge on the nasal surface or settle out by gravity depending on size. With these functions in mind, the nose is much more than simply a sniffing and smelling organ.

The olfactory cleft is situated in back of and below the eyes, or more specifically, between the median septum and the superior turbinate (see No. 6 of Figure 6.1), so that air inhaled through the nose passes near this region. A unique aspect of the location of the olfactory cleft is that inspired air does not pass directly over it. Air ascends and reaches a peak near the middle of the nasal passage where it then descends to the posterior nares. For this reason it is thought that eddy currents carry air to the olfactory region, causing joint olfaction and a deeper inspiration.[38] The total surface area of the olfactory region equals approximately one square inch in each nostril. The olfactory

receptors appear to be quite simple pigmented cells with long protoplasmic filaments extending into the air passage. It is generally believed that these hairs are affected by the odor particles initiating the sense of smell.[38] The hairs are kept moist by mucus supplied from areas adjacent to the olfactory region.

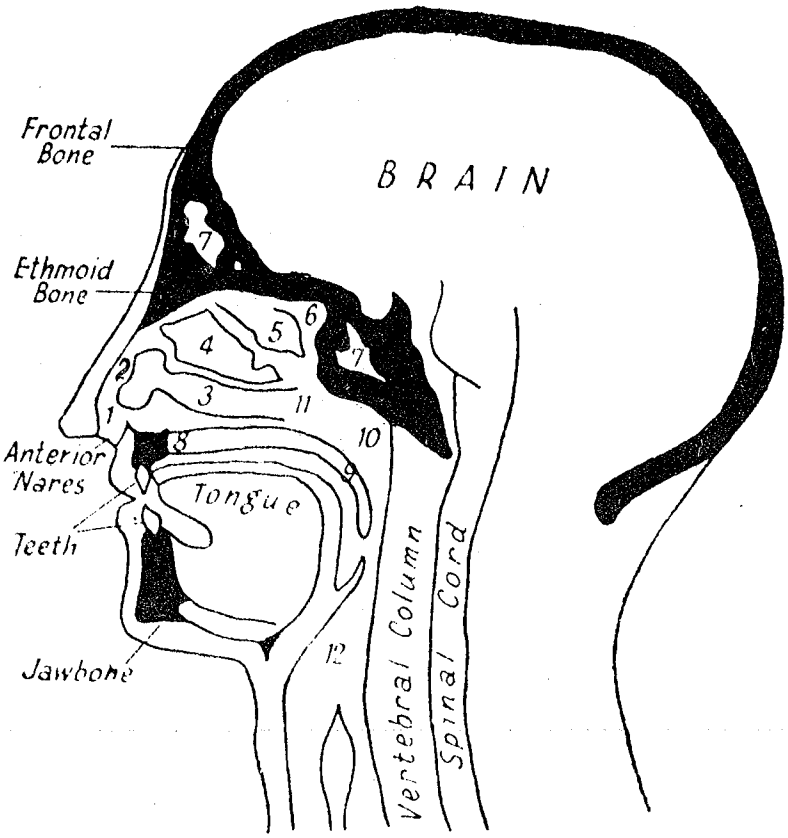


FIG. 2.—The nasal passages.

(1) Vestibule.
(2) Antrum.
(3) Inferior turbinate.
(4) Middle turbinate.
(5) Superior turbinate.
(6) Olfactory cleft.
(7) Sinuses.
(8) Hard palate.
(9) Soft palate.
(10) Naso-pharynx.
(11) Posterior nares.
(12) Pharynx.

Figure 6.1 The nasal passages (Moncrieff, 1968).

For a substance to have an odor it must be volatile, soluble in water, and soluble in lipids.[4] A characteristic of any given volatile substance is that it sheds molecules into the air, which is a prerequisite for the inhalation of its molecules. The second prerequisite of water solubility of the molecule is necessary for the molecule to penetrate the moist mucus layer. If the molecule is not water soluble it cannot penetrate to the nerve endings and initiate a stimulus. The third property of the molecule, lipid solubility, is necessary for penetration of the nerve endings lipid sheath, a component of the surface membranes of all cells. When the odoriferous molecule penetrates and stimulates the olfactory cleft, the sense of smell is initiated. The olfactory nerve, situated in the olfactory cleft, connects the region to the cerebrum. The cerebrum is the seat of intelligence and of the 12 cranial nerves, the olfactory nerve is the only one to enter this high an area of the brain. It is in the cerebrum that the sensation is interpreted and an odor is recognized as such.

The first step in the perception of an odor is the reaction between the molecules of the odorant and the chemical receptor. The second step is the recognition and differentiation of odors, a point on which opinions differ. One of the more plausible theories of recognition and differentiation is the sterochemical theory of odor put forth by Amoore et al.[4] Amoore initiated a literature search to identify odorous compounds. This search yielded 600 compounds that he was able to group in seven categories according to structures.

Amoore's hypothesis falls into the "lock and key" category. Basically, the theory states that the seven primary odors (see Figure 6.2) can be matched to seven kinds of olfactory receptors. These receptor sites would be similar in size and shape to particular molecules, with some molecules being able to fit into two different slots, defining a complex odor. From the seven primary odors, every known odor can be made by mixing in different proportions. Amoore has supported his theory by looking at molecular structure, predicting its odor, and verifying it with an odor panel.

Amoore has also looked at specific anosmia, the little known phenomenon of odor blindness. In his experiments, Amoore studied what he called Davis Deficiency, the inability to perceive the sweaty odor of isobutyric acid.[3] Subjects in this experiment were tested for their olfactory thresholds towards a group of 18 purified compounds related in one way or another to isobutyric acid. The compounds surveyed were used to test the different variables thought to be associated with anosmia: molecular size and weight; molecular shape, and functional group. By exposing an anosmiac to differing molecules and determining which could and could not be smelled, Amoore was able to determine the approximate size and shape of the isobutyric receptor site, or what Amoore contends is one of the seven primary odors. This research indicated that about four percent of the test population was anosmiac to a particular odor. If this is the case, it can be postulated that up to 28 percent of a given population may be anosmiac to at least one of the seven primary odors.

This casts a shadow on some of the research on subjective odor levels. Possibly some people in these tests who did not rate an odor as objectionable could not even smell it.

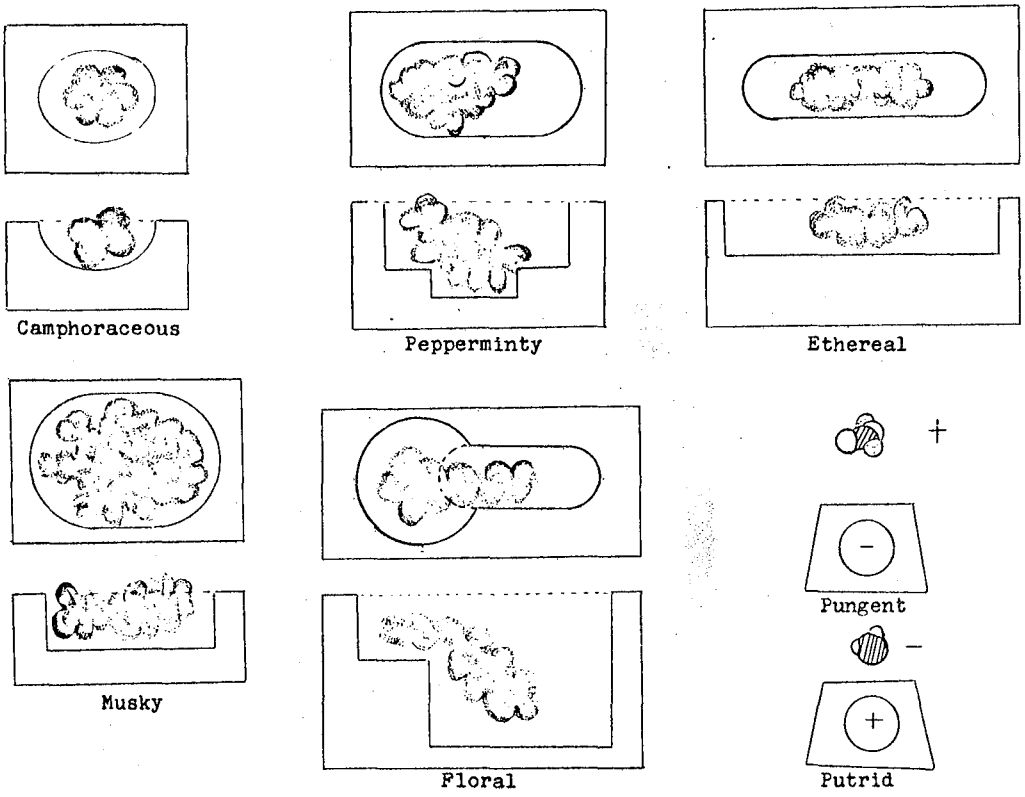


Figure 6.2 Shape of the seven primary odor receptor sites (Amoore, 1964)

Dravnieks puts forth a favorable explanation of olfaction different than Amoore's lock and key theory.[16] Dravnieks states that odors have two major dimensions: 1) psychophysical or sensory, and 2) analytical. It is the psychophysical component of the odor that reflects the sensation. In Dravnieks' article, "The Possible Mechanisms of Olfaction," he states that odor sensation is conveyed to the nerves in the form of electrical potential impulses. The impulses in the odor of a few millivolts are amplified on a ferroelectric substrate, causing spontaneous polarization. The odor is recognized primarily by the pulse frequency that is generated.

The theories of olfaction are by no means limited to Dravnieks and Amoore. At the present time, these are accepted as some of the more plausible theories of olfaction. For reader reference some other theories of olfaction are: Liederitz (1959) combines psychology and superstition to explain olfaction; Juhasz (1926) developed the "pitch" theory; Alexander (1951) the "enzyme" theory; Ruzicka (1920) the "osmoceptor" theory; and Burgenberg, DeJong and Saubert (1937) the "colloidal" theory.

ODOR THRESHOLD

The threshold of an odor is the minimum concentration at which it can be detected at a statistically significant level. Usually threshold refers to that concentration at which a particular odor can be detected in 50 percent of trials, but in some instances it has been defined as the first concentration at which 100 percent of the people can recognize the odor.[14,31] On the other hand, the recognition odor threshold is defined as the first concentration at which an observer can positively identify the odor quality of the odorant chemical and maintain some consistency of response at all higher concentration levels.[31]

Doubling the concentration of an odor at a given concentration does not double the perceived intensity. Instead, intensity varies in proportion to the logarithm of the concentration in accordance with other physical stimuli. The intensity of any physiological stimuli can be expressed by the Weber-Freshener Law: sensation = k (log of stimulus intensity).[40] Dravnieks instead uses $S = kC^n$ which is called the psychophysical power function.[14] S is the perceived

intensity with S being assigned a number proportional to the intensity of odor sensation; C is the odorant concentration; and k and n are coefficients. Values of n for odors are less than unity because doubling the odor does not double the perceived intensity. In general, "values of n for odor sources that occur in the hospital are not known."[14]

Individuals vary in ability to detect odors either due to specific anosmia or intra-individual sensitivity. Sensitivity to odors should follow a Gaussian distribution when concentration is expressed in logarithmic form.

Odor thresholds of different chemicals varys immensely. Odor threshold determination of 53 odorant chemicals as tested by Leonardos et al showed that Trimethyl Amine has a threshold of .00021 ppm versus Acetone with a threshold of 100 ppm.[31] This would indicate that extremely low concentrations of a particular chemical in the hospital can be associated with an odor problem while much higher concentrations of a different odorant might yield no problem.

ODOR CLASSIFICATION AND MEASUREMENT

All odor measurement techniques that are in use at the present time rely on the human nose. The sensory attributes that can be measured are the acceptability, quality, intensity and pervasiveness.[17] When measuring for malodors within the hospital it is better to measure the objectionability threshold rather than the intensity threshold. These two numbers can be vastly different with the intensity threshold always lower than the objectionability threshold, because the odor must be perceived before it can be objected to. In the hospital it is usually sufficient to control objectionability rather than to eliminate the odor entirely. This is a general principal which could be used in all dwellings to conserve energy

Odor classification schemes are not standardized. Many researchers use their own classification system of defining odor scales of pleasantness or unpleasantness. Many scales use association for pleasant smells i.e., floral, pepperminty, spicy, and characterization for unpleasant odors i.e., foul, overpowering or nauseating.

There are many methods of odor measurement in use today. They are too many to discuss in the context of this paper so the reader is directed to references 2,8,17,20,24,36,39 and 42.

VENTILATION RATES AND STANDARDS

In 1935, Lehmberg initiated a laboratory study of minimum ventilation requirements by confining human subjects in an airtight box, ventilating the box and smelling the exhausted air.[30] In 1936-1937, Yaglou greatly expanded Lehmberg's preliminary work, and today he is generally considered the pioneer in the study of ventilation requirements for odor removal.

Yaglou studied the general problem of odors and tried to simulate in the laboratory conditions of ventilation as found in offices and schools. The three methods of odor control he studied were personal sanitation, ventilation and air washing. Since the experiments by Yaglou still constitute the main criteria for setting ventilation standards with regards to stale air versus fresh air, they will be recounted here in some detail.

The experimental procedure was carried out in two separate rooms adjoined by a small door. The "experimental" room was occupied by the subjects while the other room served as a control for the judges who estimated the odor intensity in the experimental room.

The air was introduced to the rooms near the ceiling through 14 in. round ducts running along the entire length of the rooms and fitted with splitters. The ducts were perforated over half of the periphery with a multitude of holes ½ in. in diameter and 2½ in. on centers, facing toward the ceiling. The recirculated air was withdrawn at floor level through a 10 in. round duct. The exhaust air was allowed to escape to the corridor through sensitive check louvres attached near the bottom of the doors.

Accurate measurements of the total air supplied to the rooms, the amount recirculated, and that taken from out of doors, were made by means of thinplate orifices designed in accordance with the A.S.M.E. standards and checked against a calibrated venturi meter. Control of the air flow was by means of variable speed motors and different size orifices.

Dry- and wet-bulb temperatures were measured by means of aspirating psychrometers, and the air movement by means of kata-thermometers, or globe anemometers. Measurements of carbon dioxide were made by means of a 20 cc modified Haldane gas analysis appratus for CO_2 only.

The experimental room was occupied by 3,7, and 14 subjects in different series of experiments, so as to obtain 3 different floor areas per person, i.e., 11, 22, and 52 sq ft and 3 different air spaces 100, 200 and 470 cu ft approximately. The air flow in the experimental room was varied from about 2 to 30 cfm per person in different experiments. In one series the total air supply remained constant at 30 cfm per person but the amount taken from out of doors was varied from 20 to 30 cfm. In another series only outdoor air was circulated through the experimental room. In a third series, the mixture of outdoor and recirculated air was washed, cooled, humidified or dehumidified in order to determine the effect of these processes on odor removal and on minimum ventilation requirements.

According to the scale in Table 6.3 the agreement between judges was usually within $\pm$ ½ point on the scale, as in Lehmberg's work, once they have become familiar with the scale.

Altogether 60 men and women with more or less normal sense of smell served as judges. They were drawn from employees of the school and graduate students. Two of the judges devoted their entire time to the tests. Others, usually from 8 to 15 persons in each test, were called in as needed. After a short stay in the control room, they passed to the experimental room to smell the air, and were then released. All records were kept confidential by two men who ran the tests.

SENSORY INTENSITY SCALE OF BODY ODOR

ODOR INTENSITY INDEX	CHARACTERISTIC TERM	QUALIFICATION
0	None	No perceptible odor.
½	Threshold	Very faint, barely detectable by trained judges; usually imperceptible to untrained persons.
1	Definite	Readily detectable by all normal persons but not objectionable.
2	Moderate	Neither pleasant nor disagreeable. Little or no objection. Allowable limit in rooms.
3	Strong	Objectionable. Air regarded with disfavor.
4	Very strong	Forcible, disagreeable.
5	Overpowering	Nauseating.

Table 6.3

The results of this study indicated that the strength of the perceived body odors upon entering the experimental room varied inversely as the log of the outdoor air supply. The minimum air supply needed to bring the odor to the allowable intensity of two Yaglou's scale with 200 cubic feet of air space per person was about 16 cfm per person. Grade school children in spite of smaller body surfaces required 21 cfm per child to keep the odor level not objectionable. Under identical conditions, adolescents, age 16 and up, required the same ventilation rates as adults. Sex was not a factor in odor intensity. With an air space of 470 cubic feet per person, which is representative of conditions in the home, the air requirement with respect to body odors was reduced to seven cfm.

Air washing, humidifying or cooling recirculated air removed a considerable amount of odors in Yaglou's experiments. Air reduction in the ventilation requirement for outdoor air during recirculation from 16 to 13 cfm was realized by any of these treatments. This represents a 20 percent reduction in ventilation and would result in energy saving since proportionally less air must be conditioned.

One of the unusual aspects of this study was that a cross section of socio-economic groups was tested individually as follows: a) 177 sedentary men and women of average socio-economic status; b) 62 grade school children of average socio-economic status; c) eight laborers; d) seven school children of the poorest class, and e) 28 school children of the better class. Socio-economic status was a significant factor during these experiments. For example, with equal ventilation rates, laborers were much more odoriferous than medical students (a). In fact the ventilation rate had to be increased by 50 percent in order to keep the odor level below 2 units on Yaglou's scale (see Table 6.3).

Yaglou's study also showed a difference in odor intensity perceived by the subjects and the investigators. Subjects generally agreed that upon entering the test room, air quality was good. Near the middle of the test odor quality was perceived to have deteriorated, but at the end of the test subjects could not delineate between the middle and later periods, indicating olfactory sensitization. On the other hand, the judges were able to distinguish between these periods and noted a sharp deterioration in air quality as the length of confinement increased. The judges required an airflow of 16 cfm in

order to consider the odor not objectionable. Subjects were satisfied with almost any air velocity over three cfm as long as air space exceeded 100 cubic feet.

Another significant finding was that untreated, recirculated air in any amount had absolutely no effect in diluting odor intensity and improving air quality.

The results of Yaglou's second study on ventilation requirements were reported in 1937. This study dealt with spontaneous disappearance of body odors with time, changes in odor removal efficiency depending on room size and ventilator location, and adsorption of odors on room surfaces. Yaglou's work on body odor degradation was the first work of its kind. One of his conclusions was that body odors disappeared with time. He attributed this to oxidation and to the loss of moisture from the organic component of body odor to the atmosphere. Human odors decayed within four minutes of a subject leaving the room even with no ventilation. The decay time of tobacco smoke was also studied and it was shown to exceed 17 hours and up depending on the number of cigarettes smoked.

The arrangements of persons within a room in relationship to the location of the air supply had a pronounced effect on odor removal. These experiments emphasized the importance of a large area for each person. The greater the area per person the lower the rate of ventilation needed just so there is enough air to move across the occupied zone. The air was free to move across this space removing odors in the larger room. Reducing room size necessitated increased ventilation rates allowing the air to move quickly to the exhaust and thus lowering efficiency.

The experiments by Yaglou showed that adsorption of odors on walls, ceilings and floors was minimal and did not greatly effect odor intensity. Other authors have looked into the odor adsorbing properties of certain materials, but their conclusions cannot be extrapolated to body odor adsorption.

Hopper studied the odor retention characteristics of cotton, wool, nylon and rayon.[21] Iso-amyl acetate was used as the odor producing agent. Of the fabrics tested, rayon did not adsorb enough odor to be measured. Test results on the other fabrics showed that odor pickup and odor decay for nylon and cotton are essentially the same. Wool adsorbed less odor during a 24-hour period and its rate of odor decay was lower than that of nylon and cotton. The maximum odor adsorption and retention of material was dependent on both the temperature and the relative humidity. Maximum odor adsorption occurred at 75^{o} F and 50 percent relative humidity, Odor adsorption at lower and higher temperatures was considerably lower.

The relationship of humidity and odor was more thoroughly studied by Kuehner.[27,28] His results showed that high humidity "reduces the acuity of the sense of smell and accelerates the volatilization of odors from certain household substances." This produces a quandry which must be balanced to derive beneficial effects. Where emission of odors is intrinsic such as with paints and linoleum it would be beneficial to keep humidity low which would keep odor emission low. On the other hand when odors become adsorbed, ventilating with high humidity will help cleanse the surface and at the same time reduce the aquity of the sense of smell.

An extensive literature search revealed that there is no research relating to odor adsorption by materials from cleaning agents and chemicals used in the hospital. One could surmise that very reactive chemicals such as alcohols would leave no residual odors and be a transient problem, but the multiplicity of other agents used could indeed cause trouble.

In 1935 Houghton studied classroom odors with reduced outside air supply. He controlled the heat and ventilation in some classrooms and determined that five cfm of fresh air is the absolute minimum necessary to keep odor levels unobjectionable.[23] Houghton's conclusions paralleled Yaglou's, showing that odors are little noticed by room occupants but are very noticeable to a person entering an odoriferous area from a less odoriferous area.

Rae and Smith reported a study in 1976 on hospital ward odors.[43] Tests were carried out to determine the effect of mechanical ventilation and recirculation rates on subjective odor levels. Rae and Smith stated in opening remarks of their paper that:

> *an extensive literature survey revealed little previous relevant work on subjective odor levels, current practice in regards to odor being largely based on rule of thumb figures derived from tests carried out in the 1930s with subjects in small chambers (Yaglou, Riley and Loggins, 1936, Yaglou and Witheridge, 1937). We were therefore obliged to commence testing work in a position of relative ignorance as to what conditions would occur in the test situation.*

Odor levels in the hospital ward were rated on a scale of one to four, with one being barely noticeable background odors and four being intolerable. During the two-year period in which this study was carried out, two

occasions of odor conditions were classified as acute. The critical zone of patient and staff complaints was found to be directly within the source room, adjacent rooms and linking corridor. "No significant effect of either air change rate or percentage recirculation" was found to influence the subjective odor level in the ward areas. Ventilation rates during the study ranged from three to six air changes per hour.

It should be noted that this study was carried out in Scotland where the social structure of the hospital setting differs from that in the United States. Large ward areas are not uncommon and in the experimental setting four or five patients were located in a room of 225 square feet which included a bathroom. Patient isolation is strongly frowned upon and it would be unheard of to isolate a patient odor source even if that person was the only source. In the United States the acutely malodorous conditions encountered in this experiment from patient sources could have been handled by isolation. In view of the fact that six air changes per hour were not sufficient to cleanse the air in this experimental situation the authors felt that an excess of 20 air changes per hour would be necessary to reduce odor to threshold levels. From an energy point of view, this would be costly and wasteful. Isolation of the odor source seems more preferable in what appears to be a relative infrequent occurrence.

One weak aspect of this study is that outsiders or impartial judges were not used to survey the odor intensity, but rather hospital workers' and patient's views were taken. Since the odors were emanating from patient sources, the patient might not admit to

perceiving an odor problem especially if they were the source. The hospital staff would presumably be acclimated to hospital odors and not perceive an odor as "troublesome" or "intolerable."

Current Standards for Odor Control

The technology of odor control is not as sophisticated as other aspects of building heating, ventilating and air conditioning engineering. There is an absence of standards for odorant production and acceptability and only limited measurement tools to assess the quality of an odorous space or the performance of odorant control mechanisms. The present hospital ventilation standards seem to be based on what is thought to be a need for airborne biological agent control. To try to apply these standards to odor control is a futile exercise.

Examination of state conformance to hospital ventilation standards (Chapter 2) revealed that the standards most closely adhered to are the 1974 Hill-Burton Standard. These standards do not address themselves to reducing odors (Table 2.2). In some areas it is required that the air be filtered but this is for bacterial and particle removal only. This standard also allows for an "optional" recirculation of air in some areas. Yaglou's study showed that recirculated "uncleaned" air has no functional capacity for eliminating or diluting odors. In other words, from an odor standpoint, recirculation without cleaning the air of odors is ineffective.

Under the 1974 Hill-Burton Standard the operating room air change rate can be as low as five air changes per hour if 100 percent outside air is used (Table 2.2). Recently surveys indicate that anesthetic

gas levels can reach appreciable levels even if over 15 air changes an hour are used, but there is some indication that particulate concentrations in the air might be reduced and that odors might be reduced based on extrapolation of Yaglou's data.[7]

All other areas of the hospital require fewer air changes per hour. For example patient rooms are allowed a minimum of two air changes an hour of outside air. Rae and Smith showed that these ventilation rates would have to be increased 10 to 15 times to alleviate an odor problem. From an economic and energy standpoint, this is simply not feasible.

The 1978 ASHRAE Standard (Table 2.4) makes some useful recommendations regarding odor control. The standard states that

> *to control odor that is associated with some cases, activated charcoal filters or additional ventilation may be required in a central recirculating system.*[19]

A further recommendation is:

> *Most existing governmental agency design criteria and codes require all air from toilet rooms to be exhausted directly to outdoors. This requirement appears to be based upon odor control. Practical experience has shown that health facilities, with the possibile exception of nursing homes, having central toilet exhaust systems generally have sufficient dilution to render the toilet exhaust air practically odorless. For this reason, plus the need to conserve energy, it is recommended that consideration be given to recirculation of up to 50 percent of toilet room air where central systems with appropriate conditioning and filtration equipment are employed.*[19]

These ASHRAE recommendations represent a more progressive approach towards hospital ventilation standards with regard to energy conservation since they not only call for recirculation of air but outline methods for its use and possible treatment.

CONTROL OF ODORS

Some of the major directions taken in odor control are focused on incineration, oxidation, dilution, absorption and adsorption. Some of these are not applicable for use in the hospital environment and some methods of odor control have been discontinued when it was realized how dangerous they really are (i.e., ozonation) to the hospital population even though they are effective in curbing the odor problem.

Masking and Induced Anosmia

Masking is the most widely used odor control method in homes, industry, or the hospital. The reasons for this are primarily economic because masking an odor is much cheaper than any other control method. The masking of odor falls into two categories: 1) disguising the odor so it smells like something else, and 2) induced anosmia.

Disguising an odor is prevalent in our society in general. We wear perfume, use deodorant soaps and apply deodorants to our body even after we have just cleaned them, so it seems natural to disguise the odors in the air. Air sprays and fresheners work primarily in this direction. They are sprayed into the air, or emitted from "wicks" and other devices to create a new odor that is hopefully more pleasant than the old odor. Masking does not eliminate the odor source, nor are molecules causing the odor eliminated.

As previously discussed, anosmia is the inability to smell an odor. Anosmia can be induced by olfactory fatigue, by continued stimulation, or by certain drugs or chemicals. This can be used to

an advantage by spraying a chemical into the air, which dulls olfactory sense and hence causes a person to temporarily lose the sense of smell. A few minutes in fresh air or even a few sniffs of fresh air restores the sense of smell. Again, with this method as in masking, the odor source is neither reduced nor eliminated.

A major concern of masking hospital odors is that another unknown is added to the environment. An example of this is the deodorants used in the University of Minnesota Hospitals. The solid air freshener contains carageenan, pigments, surfactants, water, preservatives, oils and aromatics. The spray deodorants contain hydrocarbons, surfactants, water, oils, aromatics, petroleum distillates and a corrosion inhibitor. This is the only information available from the manufacturer on the contents of this product.[41] Chemical formulas or names needed to determine the possible toxicity of these substances were not disclosed.

In 1947 McCord published a paper concerning the safety of air deodorants.[35] His results indicated that they did not have allergenic properties, but only healthy persons were surveyed. More study is needed in this area to determine if the use of these products is safe in the hospital environment and not harmful to patients or staff.

Incineration and Oxidation

Incineration is a form of oxidation and can be used for odor control, hydrocarbon control and organic pollutant control. Almost all highly odorous pollutant gases are combustible or are changed chemically to less odoriferous compounds when burned in the presence of oxygen.[1] When concentrations of a pollutant are extremely low,

incineration works well but its application to the hospital is limited due to cost and maintenance. Another limiting factor is that after incineration the air would be too hot for recirculation.

Other forms of oxidation are chemical in nature. Chlorination and ozonation can be used to oxidize odoriferous compounds. In fact, ozonation was generally recognized method of odor control and was used in the hospital setting until it was realized how dangerous the ozone was versus the odors themselves just being a nuisance. Chlorine is another oxidizing chemical which should not be used freely around the hospital, so incineration and oxidation in hospitals for odor control are not preferable methods.

Dilution

Dilution is simply the process of adding clean air to odoriferous air and reducing the relative concentration of the odorant. The only conclusive study applicable to this process appears to be Yaglou's work. Again, from review of his data, it would seem that dilution of odoriferous air with clean air might be a solution. The problem is where the clean air is going to come from. Weather conditions such as temperature inversion might cause the "clean" outside air to be odoriferous precluding its use for dilution. Another problem is that for different odors and for different concentrations of an odorant the percentage of clean air mixed with odoriferous air will vary. Yaglou stressed the importance of using clean air and showed that odors cannot be decreased by dilution with uncleaned recirculated air.

A report published by a group in Sweden showed that airflows in older buildings are normally 40 m^3/h (23.5 cfm) per person and lower, while newer buildings have an airflow of about 70 m^3/h (41.2 cfm) per person.[13] A statistical analysis conducted by this group to determine the influence of these different rates on perceived odor intensity indicated that there was no difference at the lower versus the higher level. This study also demonstrated that even when ventilating at 70 m^3/h per person there is no noticeable improvement in the room odor, hence dilution does not seem to be a viable odor control method.

Absorption

Absorption is a diffusion process which involves the transfer of gas molecules into the liquid phase. Another name for this process is scrubbing since the odorant is washed by a liquid and absorbed into it. Air scrubbers may effectively remove odorants but the feasibility for use in recirculated air systems in the hospital is limited. These systems are fairly large and expensive to run and maintenance costs are high. This control method is also difficult to apply to a point source odor problem.

Adsorption

The principal means by which odors are controlled via adsorption is by allowing the gaseous molecules to impinge on a solid substrate so that the molecules are captured and restrained on the substrate. Hence, adsorption is a process by which gaseous molecules are captured and restrained on a solid. The most common type of adsorbant used is some form of activated carbon, although clays, gels and silicates are also in use. This process has the advantage of being able to remove organic vapors along with odor producing compounds. The problem with activated carbon is that the greatest efficiency is with

molecules of high molecular weight and gases with high boiling points. Ammonia ethylene and formaldehyde all have low molecular weights, so it should not be expected that activated charcoal would remove these substances.[44] Very stable gases such as carbon monoxide are also not be removed.

Table 6.4 lists efficiency of removal by activated carbon for many materials. Odorous compounds that are found in the hospital are checked as are some of the chemical compounds.

Talbe 6.4. Capacity of 50 minutes activated coconut charcoal for vapors.

The capacity index has the following meaning:

4–High capacity for all materials in this category. One pound takes up about 20% to 50% of its own weight—average about ⅓ (33-⅓%). This category includes most of the odor causing substances.

3–Satisfactory capacity for all items in this category. These constitute good applications but the capacity is not as high as for category 4. Adsorbs about 10 to 25% of its weight—average about 1/6 (16.7%).

2–Includes substances which are not highly adsorbed but which might be taken up sufficiently to give good service under the particular conditions of operation. These require individual checking.

1–Adsorption capacity is low for these materials. Activated charcoal cannot be satisfactorily used to remove them under ordinary circumstances.

2–Acetaldehyde
4–Acetic Acid
4–Acetic Anhydride
3–Acetone
1–Acetylene
3–Acids
3–Acrolein
4–Acrylic Acid
4–Acrylonitrile
4–Adhesives
4–Air Wick
4–Alcohol
4–Alcoholic beverages
2–Amines
2–Ammonia
4–Amyl Acetate
4–Amyl Alcohol
4–Amyl Ether
3–Animal Odors
3–Anesthetics
4–Aniline
4–Antiseptics
4–Asphalt Fumes
3–Automobile Exhaust
3–Bacteria
4–Bathroom Smells
4–Benzene
3–Bleaching Solutions
4–Body Odors
4–Bromine
4–Burned Flesh
4–Burned Food
4–Burning fat
3–Butadiene
2–Butane
4–Butanone
4–Butyl Acetate
4–Butyl Alcohol
4–Butyl Cellosolve
4–Butyl Chloride
4–Butyl Ether
2–Butylene
2–Butyne
3–Butyraldehyde
4–Butyric Acid
4–Camphor
4–Cancer Odor
4–Caprylic Acid
4–Carbolic Acid
3–Carbon Bisulfide
1–Carbon Dioxide
1–Carbon Monoxide
4–Carbon Tetrachloride
4–Cellosolve
4–Cellosolve Acetate
4–Charred Materials
4–Cheese
3–Chemicals
3–Chlorine
4–Chlorobenzene
4–Chlorobutadiene
4–Chloroform
4–Chloro Nitropropane
4–Chloropicrin
4–Cigarette Smoke
4–Citrus and other fruits
4–Cleaning Compounds
3–Coal Smoke
3–Combustion Odors
4–Cooking Odors
3–Corrosive Gases
4–Creosote
4–Cresol
4–Crotonaldehyde
4–Cyclohexane
4–Cyclohexanol
4–Cyclohexanone
4–Cyclohexene
4–Dead Animals
4–Decane
4–Decaying Substances
4–Decomposition Odors
4–Deodorants
4–Detergents
4–Dibromoethane
4–Dichlorobenzene
3–Dichlorodifluoromethane
4–Dichloroethane
4–Dichloroethylene
4–Dichloroethyl Ether
3–Dichloromonofluormethane
4–Dichloro-Nitroethane
4–Dichloropropane
3–Dichlorotetrafluoroethane
3–Diesel Fumes
3–Diethyl Amine
4–Diethyl Ketone
4–Dimethylaniline
4–Dimethylsulfate
4–Dioxane
4–Dipropyl Ketone
4–Disinfectants
4–Embalming Odors
1–Ethane
3–Ether
4–Ethyl Acetate
4–Ethyl Acrylate
4–Ethyl Alcohol
3–Ethyl Amine
4–Ethyl Benzene
3–Ethyl Bromide
3–Ethyl Chloride
3–Ethyl Ether
3–Ethyl Formate
4–Ethyl Mercaptan
4–Ethyl Silicate
1–Ethylene
4–Ethylene Chlorhydrin
4–Ethylene Dichloride
3–Ethylene Oxide
4–Essential Oils
4–Eucalyptole
3–Exhaust Fumes
4–Female Odors
4–Fertilizer
3–Film Processing Odors
4–Fish Odors
4–Floral Scents
3–Fluorotrichloromethane
4–Food Aromas
2–Formaldehyde
3–Formic Acid
2–Fuel Gases
3–Fumes
4–Gangrene
4–Garlic
4–Gasoline
4–Heptane
4–Heptylene
3–Hexane
3–Hexylene
3–Hexyne
4–Hospital Odors
4–Household Smells
1–Hydrogen
2–Hydrogen Bromide
2–Hydrogen Chloride
3–Hydrogen Cyanide
2–Hydrogen Fluoride
3–Hydrogen Iodide
2–Hydrogen Selenide
3–Hydrogen Sulfide
4–Incense
4–Indole
3–Inorganic Chemicals
3–Incomplete Combustion
3–Industrial Wastes
4–Iodine
4–Iodoform
4–Irritants
4–Isophorone
3–Isoprene
4–Isopropyl Acetate
4–Isopropyl Alcohol
4–Isopropyl Ether
4–Kerosene
4–Kitchen Odors
4–Lactic Acid
4–Lingering Odors
4–Liquid Fuels
4–Liquor Odors
4–Lubricating Oils and greases
4–Lysol
4–Masking Agents
4–Medicinal Odors
4–Melons
4–Menthol
4–Mercaptans
4–Mesityl Oxide
1–Methane
3–Methyl Acetate
4–Methyl Acrylate
3–Methyl Alcohol
3–Methyl Bromide
4–Methyl Butyl Ketone
4–Methyl Cellosolve
4–Methyl Cellosolve Acetate
3–Methyl Chloride
4–Methyl Chloroform
3–Methyl Ether
4–Methyl Ethyl Ketone
3–Methyl Formate
4–Methyl Isobutyl Ketone
4–Methyl Mercaptan
3–Methylal
4–Methylcyclohexane
4–Methylcyclohexanol
4–Methylcyclohexanone
4–Methylene Chloride
3–Mildew
4–Mixed Odors
3–Mold
4–Monochlorobenzene
3–Monofluorotrichloromethane
4–Moth Balls
4–Naphtha (Coal tar)
4–Naphtha (Petroleum)
4–Naphthalene
4–Nicotine
3–Nitric Acid
4–Nitro Benzenes
4–Nitroethane
2–Nitrogen Dioxide
4–Nitroglycerine
4–Nitromethane
4–Nitropropane
4–Nitrotoluene
4–Nonane
3–Noxious Gases
4–Octalene
4–Octane
4–Odors
4–Odorants
4–Onions
4–Organic Chemicals
4–Ozone
4–Packing House Odors
4–Paint and Redecorating Odors
4–Palmitic Acid
4–Paper Deteriorations
4–Paradichlorbenzine
4–Paste and glue
3–Pentane
4–Pentanone
3–Pentylene
3–Pentyne
4–Perchloroethylene
4–Perfumes, cosmetics
4–Perspirations
4–Persistent Odors
4–Pet Odors
4–Phenol
3–Phosgene
4–Pitch
4–Plastics
3–Poison Gases
3–Pollen
4–Popcorn and Candy
4–Poultry Odors
2–Propane
3–Propionaldehyde
4–Propionic Acid
4–Propyl Acetate
4–Propyl Alcohol
4–Propyl Chloride
4–Propyl Ether
4–Propyl Mercaptan
2–Propylene
2–Propyne
3–Putrefying Substances
4–Putrescine
4–Pyridine
2–Radiation Products
4–Rancid Oils
3–Refrigerant-12
4–Resins
4–Reodorants
4–Ripening Fruits
4–Rubber
4–Sauerkraut
4–Sewer Odors
4–Skatole
3–Slaughtering Odors
4–Smog
4–Soaps
4–Smoke
3–Solvents
4–Sour Milks
4–Spilled Beverages
4–Spoiled Food Stuffs
4–Stale Odors
4–Stoddard Solvent
4–Stuffiness
4–Styrene Monomer
4–Sulfur Compounds
2–Sulfur Dioxide
3–Sulfur Trioxide
4–Sulfuric Acid
4–Tar
3–Tarnishing Gases
4–Tetrachloroethane
4–Tetrachloroethylene
4–Theatrical Makeup Odors
4–Tobacco Smoke
4–Toilet Odors
4–Toluene
4–Toluidine
4–Trichlorethylene
4–Turpentine
4–Urea
4–Uric Acid
4–Valeric Acid
4–Valericaldehyde
4–Vapors
4–Varnish Fumes
4–Vinegar
3–Vinyl Chloride
3–Viruses
3–Volatile Materials
4–Waste Products
3–Wood Alcohol
4–Xylene

Some of the contaminants listed in the table are specific chemical compounds, some represent classes of compounds, and others are mixtures and of variable composition. Activated charcoal's capacity for odors varies somewhat with the concentration in air, with humidity and temperature, and with the actual velocity used through the filters. The numbers given represent typical or average conditions and might vary in specific instances. The values in the table have been assembled from many sources including laboratory tests and field experience. In cases where numerical values were not available, the author has listed his opinion of the probable capacity based on general experience. The table should be used as a general guide only.

The charcoal referred to in Table 6.4 is 50-minute activated coconut charcoal used widely for air purification. The 50 minutes refers to a test procedure used to determine the adsorptive capacity of the charcoal. When examining the capacity index at the top of the chart, some interpretation is necessary because these values are misleading. For example, "pyrdine, valeric acid, and methylketone are all given a 'four' rating. However, the odor threshold as well as the maximum allowable concentration for the three substances varies significantly. Valeric acid has a very unpleasant odor in the low parts per billion range. Methyl ethyl ketone, on the other hand, can be tolerated at several hundred parts-per-million in air. Hence, although the maximum capacity of activated charcoal without regard to concentration for those substances may be similar, the actual usable capacity for odor removal applications will vary markedly due to the large differences in odor threshold and odor characteristic." [44]

Other shortcomings of the activated carbon are in part due to the way it has to be installed in recirculated air systems. The adsorption beds on a system such as this have to be packed very loosely. This is necessary to keep resistance minimal so increased energy is not needed to force the air through. The loosely packed bed results in decreased dwell time of the air, decreasing efficiency. Factors influencing the adsorbate efficiency include dwell time, adsorbate density, adsorbant packing, vapor pressure of adsorbate and temperature and pressure of the system.

In an air recirculation system activated charcoal filters are the method of choice for odor control. These units can be self-contained, can be applied to point source control, and require low maintenance.

CONCLUSIONS

Odors are a recurring problem within today's complex hospital environment and do cause patient, staff and visitor discomfort.

The primary sources of odors include the patient as well as the multitude of cleaning agents, disinfectants, deodorants and deodorizers which are used indiscriminantly throughout the hospital. Deodorants and deodorizers simply mask the odorant or induce anosmia and do not remove the odor causing particles.

Ventilation per se can not be used for control of odorants since odors vary as a log function and ventilation rates in excess of 20 air changes per hour may be necessary to reduce a strong odor to an acceptable level.

When discussing odors in the context of a hospital problem, it is better to state the odor objectionability threshold and not the threshold concentration of an odorant. It is not practical from an energy standpoint to dilute the odor below threshold when it would suffice to dilute the odor to its objectionability threshold, since the latter might require orders of magnitude less dilution. Another major point of concern is whether or not an odor should be diluted to the objectionability threshold for hospital staff, patients, or visitors. This decision could greatly influence ventilation requirements and system cost because visitors would most probably have a lower objectionability threshold than the others, necessitating increased air treatment.

Point source control should be applied to odor control. This could be most expediently carried out by isolating the source and recirculating the air through an activated carbon filter. Filtering air through activated carbon filters would reduce the odorant concentration as well as reduce the levels of airborne chemical contaminants present in the air.

Yaglou's work needs further study and validation in terms of today's hospital environment. It must be determined if odorant concentrations acceptable in 1936 are acceptable today and have the same perceived intensity in today's society as they did then.

References

1. American Industrial Hygiene Association. Air Pollution Manual Part II. Published by Industrial Hygiene Association, Detroit, Michigan, 1968.

2. American Society for Testing and Materials. Manual on Sensory Testing Methods. ASTM Technical Publication No. 434, Philadelphia, Pennsylvania, 1968.

3. AMOORE, S. E. Specific anosmia: a clue to the olfactory code. Nature, 214: 1095-1098, June 1967.

4. AMOORE, J. E. et al. The streochemical theory of odor. Scientific American, 42-49, February 1964.

5. BARNEBEY, H. L. Activated charcoal for air purification. ASHRAE Transactions, 64: 485-502, 1958.

6. BISHOP, R. Odor. Unpublished Plan B paper presented to the School of Public Health, University of Minnesota, Minneapolis, 1963.

7. Carlson Keith, Industrial Hygienist, University of Minnesota, personal communication, 1978.

8. CHEREMISINOFF and YOUNG. Industrial odor technology assessment. Published by Ann Arbor Science, Ann Arbor, Michigan, 1975.

9. CLAPHAN, T. M. et al. Activated carbon-odorant removal from air quantified. ASHRAE Transactions, 76(2145): 75-86, 1970.

10. COMSOLAZIO, W.V. et al. Minimal replenishment air required for living spaces. ASHVE Transactions, 53: 127-151, 1947.

11. Control of odors and gaseous contaminants. Chapter 33, ASHRAE Handbook 1976 Systems. Published by ASHRAE New York, New York 1976.

12. DABUE, R. R. Fundamentals of odor control. WPCF, 44(4): 583-594, April 1972.

13. Dimensioning air treatment plants in hospitals. Stockholm, Sweden Translated by Emil Fossan, State Department, Washington, D.C., July 1978.

14. DRAVNIEKS, A. Effect of increase in odorant concentration on detectability and intesity of odor, 1978.

15. DRAVNIEKS, A. Fundamental considerations and methods for measuring air pollution odors. Paper presented at the 6th International Symposium on Olfaction and Taste, Gifsuyvette, France, July 1977.

16. DRAVNIEKS, A. Possible method of olfaction. Science, 4825: 245-247, April 1962.

17. DUFEA, R. A. Appraisal of odor-measurement techniques. Journal of the Air Pollution Control Association, 18(7): 472-474, July 1968.

18. HARPER, R. et al. Odor description and odor classification. Published by J. and A. Churchill Ltd., London,1968.

19. Health Facilities, Chapter 7, ASHRAE Handbook and Product Directory, 1976 Aplications, Published by ASHRAE, New York, New York, 1978.

20. HEMEON, W. C. Technique and apparatus for quantitative measurement of odor emissions. APCA Journal, 18(3): 166-170, March 1968.

21. HOPPER, W. F. Surface odor adsorption and retention properties of surfaces. ASHRAE Transactions, 65: 735-744, 1959.

22. Hospital Ventilation Standards and Energy Conservation. Proceedings of the 1st International Working Conference. (University of Minnesota, Minneapolis), 1978.

23. HOUGHTON, F. C. et al. Classroom odors with reduced outside air supply. ASHVE Transactions, 41: 253-267, 1935.

24. JANSSEN, L. Considerations and methods in odor measurement. (Unpublished Plan B paper presented to the School of Public Health, University of Minnesota, Minneapolis, Minnesota). 1978

25. KERKA, W. F. Evaluation procedure for odor control methods. ASHRAE Transactions, 67(196): 507-525, 1961.

26. KUEHNER, R. L. The bacteria and odor control problem in occupied spaces. ASHVE Transactions, 59: 77-96, 1953.

27. KUEHNER, R. L. The effects of moisture content on the diffusion of odors in the air. ASHVE Transactions, 53: 77-89, 1947.

28. KUEHNER, R. L. Humidity effects on the odor problem. ASHVE Transactions. 62: 249-256, 1956.

29. LARGEY, G.P. and B. WATSON. The sociology of odors. American Journal Sociology, 77(6): 1021-1034, May 1972.

30. LEHMBERG, W.H. and K. MORSE. A Laboratory study of minimum ventilation requirements: ventilation box experiments. ASHVE Transactions, 41: 157-171, 1935.

31. LEONARDOS, G. et al. Odor threshold determinations of 53 odorant chemicals. Presented at the 61st Annual Meeting of the Air Pollution Control Association, St. Paul, Minnesota June 23-27, 1968.

32. LEONARDOS, G. and D.A. KENDALL. Questionaire study on odor problems of enclosed space. ASHRAE Transactions, 77: 101-112, 1971

33. MAPES, W.H. and R.F. VANCE. Efficiency evaluation of odor control devices. ASHRAE Transactions, 77(2): 52-57, 1971.

34. McCARTNEY, W. Olfaction and odors. Published by Springer-Verlag Berline-Heidelberg, New York, 1968.

35. McCORD, C.P. Safety of air deodorants. Hospital Topics and Buyer, 25(3): 29-30, March 1947.

36. MILLS, J. et al. Quantitative odor measurement. Journal of Air Pollution Control Association, 13(10): October 1963.

37. MONCRIEFF, R.W., 1966. Odor Preferences. Leonard Hill: London 1966.

38. MONCRIEFF, R.W., 1967. The chemical senses. Leonard Hill: London 1966.

39. MURA, W.R. Subjective odor measurement. Unpublished Plan B Paper presented to the School of Public Health, University of Minnesota, 1971.

40. Odors, Chapter 12. ASHRAE Fundamentals Handbook 1977. ASHRAE New York, New York, 1977.

41. Personal Communication with air cleaning product manufacturers, 1978.

42. RADDEN, E. Measurement and control of odor. Unpublished Plan B paper presented to the School of Public Health, University of Minnesota, Minneapolis, Minnesota,1963.

43. RAE, A. and R. M. SMITH. Subjective odor levels in an air conditioned hospital ward. Applied Ergonomics, 7(1): 27-33, 1976.

44. STAKAVICH, A.J. The capacity of activated charcoal under dynamic conditions for selected atmospheric contaminants in the low parts-per million range. In papers presented at the Symposium on Odors and Odorants: The Engineering View. ASHRAE Semi-Annual Meeting, Chicago, Illinois, January 27-30, 1969.

45. TURK, A. et al. Human responses to environmental odors. Academic Press, New York, 1974.

46. YAGLOU, C.P. Ventilation requirements. ASHVE Transactions, 42: 133-162, 1936.

47. YAGLOU, C.P. and W.N. WITHERIDGE. Ventilation requirements Part 2. ASHVE Transactions, 43: 423-436, 1937.

Chapter 7

CONCLUSIONS AND RECOMMENDATIONS

Hospitals are designed, constructed, and operated in a complex environment requiring adherance to multitudinous standards promulgated by a variety of regulatory agencies and standards organizations. In the ventilation area, applicable standards have different objectives, based on differing and undocumented criteria, and thus a lack of common understanding as to interpretation exists. Nonetheless, airborne infection control--a problem unique to hospitals and other health care facilities--has traditionally been the dominant issue in hospital ventilation standards. The vast majority of the standards reviewed in Chapter 2 specify large quantities of outdoor air, ostensibly as a means of infection control. Heating and cooling of this air alone make hospital building space considerably more energy intensive than its commercial counterpart. An additional contributing factor is a stringent thermal requirement, typically $75^{o}F$ in much of the hospital in combination with a limited humidity range.

Overall, the present strategy of hospital ventilation design standards appears to be that of specification of a desired environmental condition which can be produced by application of extant HVAC engineering technology, without regard to capital and operating costs or to energy consumption. Unfortunately, as the preceding literature summary suggests, these standards appear to be excessively conservative, at least in terms of the environmental factors they are intended to control.

An energy conservation mandate for hospitals will greatly constrain the present approach and in fact, will require development of a completely new strategy for hospital ventilation standards. The preceding chapters, in combination with appropriate position statements developed by the 1978 International Working Conference (see Appendix A), suggest some principles on which a new, energy conservation-conscious standard can be based. These principles are technically defensible within the present state of knowledge and will not compromise the health, safety and comfort of patients and staff. Nonetheless, the pervasive faith in ventilation as a means of airborne infection control evident throughout the health care community, will undoubtedly create resistance to adoption of these principles.

These principles are summarized in this chapter together with recommendations for supporting research necessary to fill information gaps prior to formulation of formal standards.

PRINCIPLES

Prior to delineating this set of principles, it is necessary to clarify some ventilation terminology used inconsistently in the literature. The following vocabulary, from American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. (ASHRAE) sources, is used herein:

> *AIR, OUTDOOR: air taken from outdoors and therefore not previously circulated through the system.*
>
> *AIR, RECIRCULATED: return air passed through the conditioner before being resupplied to the conditioned space.*

AIR, VENTILATION: that portion of supply air which comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space.

VENTILATION: the process of supplying ventilation air to any space by natural or mechanical means. (Provision must be made for simultaneous removal of air from the space)

The following principles are generally applicable to all hospital spaces. They cannot be unilaterally applied, however, without consideration of the unique characteristics of particular spaces such as operating rooms, intensive care units, and isolation rooms. Such spaces can be considered as micro-environments imposing special ventilation requirements which are not applicable to the hospital as a whole.

1. All hospital spaces other than those used directly for patient care or where unusual health and safety hazards exist, should comply with appropriate ASHRAE energy conservation standards for new or existing commercial buildings.
2. Airborne microorganisms play a minor role in the incidence of nosocomial infections. Therefore, means of minimizing the numbers of airborne biological agents other than by use of outdoor air can be emphasized, and hospital ventilation standards do not need to be based on control of these agents.
3. Since odor perception versus concentration is a logarithmic function, the outdoor air required to reduce acute odors in the hospital to an acceptable level can be very high. By the same reasoning, low level prevailing odors which are satisfactorily

controlled with present ventilation systems are not likely to become problems with a moderate reduction in outdoor air quantities.

Therefore, it may be desirable to control odors at their sources and to eliminate odorous compounds from the hospital environment to the maximum extent possible. This means that overall ventilation of the building space would not be the major odor control measure and that a new hospital ventilation standard need not be based on reduction of acute odors to acceptable levels. Nonetheless, the use of ventilation air for point source control in specific situations should be considered.

4. Hospital housekeeping functions are carried out daily using a variety of soaps, shampoos, furniture polish, organic solvents, bactercidal compounds, etc., many of which are quite volatile. The chemical contaminant load added to the hospital air environment is unknown, but many of these compounds are toxic, presenting possible occupational health hazards. Most hospitals are using far too many products for cleaning and disinfection purposes and are frequently not aware of their chemical composition. This situation dictates that considerable care be taken in assessing the implications of reducing outdoor air requirements. However, it is quite likely that the quantities and varieties of these cleaning materials can be reduced, allowing reduciton of dilution (outdoor) air requirements.

An additional contribution to the chemical contaminant load is the off-gassing of construction materials, which must be considered in evaluating ventilation requirements.

An outdoor air requirement for control of the prevailing chemical contaminant load will have to be established. The use of additional ventilation air for point source control such as by laboratory hoods, kitchen hoods, and waste anesthetic gases scavenging systems should, however, be considered.

5. Increasing emphasis is being placed on humidity control in hospital ventilation standards. From an energy consumption standpoint, this is an expensive operation. It is quite clear that with respect to patient, staff and visitor comfort, humidity is a minor factor when the temperature is in the comfort envelope (see ASHRAE Standard 55-74). More and more, however, very sensitive electronic patient diagnostic and monitoring equipment is being used in hospitals. In general, such equipment is very sensitive to both high and low moisture levels. It is therefore anticipated that humidity standards will probably have to be based on the requirements for the proper operation of electronic equipment and the need to prevent moisture damage to hospital equipment and structures. Other measures can be utilized for control of humidity-dependent airborne biological agent transport, such as skin shedding and allergenic mites, as necessary.

6. Both the proposed Hill-Burton Standard (Table2.1) (as well as earlier versions) and the ASHRAE Handbook (Table 2.4) specify

75^{o}F dry-bulb temperature for large parts of the hospital. There is no known technical justification for this requirement other than it lies at the middle of the comfort envelope defined in ASHRAE Standard 55-74. Adoption of Principle 1 (above) will relax this requirement for "hospital spaces other than those used directly for patient care or where unusual health and safety hazards exist."

In those spaces used directly for patient care, as Chapter 5 suggests, it is becoming increasingly apparent that a single temperature cannot satisfy all patient conditions, and thus that a range should be allowable. Further, for many patient conditions, temperature could float on a seasonal basis without compromising health and well-being. Thus a new standard could specify a wide range of, say, 65^{o}F to 78^{o}F, with individual room or zone controls in all patient care areas that are presently required to be maintained at 75^{o}F. This new standard would not apply to those areas that are allowed a range under present standards, such as operating rooms. Adoption of this principle would inherently accommodate the micro-environment control premise stated above for accommodation of specific patient conditions.

To effect both this principle and Principle 1, some changes in operating procedures, such as keeping patient room doors closed and elimination of open-backed gowns, might be necessary.

In summary, the above principles tend to reduce dependence on outdoor air for control of the unique hazards in hospitals. Instead, these hazards are to be managed by control of particular micro-environments,

i.e., point source control. Thus, ventilation air criteria will become analagous to that for other building spaces. Outdoor air quantities can be based on requirements for the various exhaust systems (toilets, kitchens, laboratory hoods, etc.), reduction of prevailing chemical contaminant load to safe levels, and for control of prevailing odors, such as body odors and those emanating from cleaning materials. Recirculated air can be used for temperature and humidity control.

In implementing these principles, it must be recognized that concurrent changes in hospital operating procedures will be required, some of which require additional research as outlined below.

SUPPORTING RESEARCH RECOMMENDATIONS

1. Describe the approaches which should be taken in the hospital to minimize the dissemination of biological agents into the air. These will have to go hand-in-hand with the reduced ventilation requirements. Although it is anticipated that they can be based principally on existing technology, some new confirmation studies may be appropriate.
2. Develop an understanding of the variety, quantities and concentration of odors in the hospital environment.
3. Based on Recommendation 2, develop strategies for controlling odors at their source as well as eliminating as many sources as possible from the hospital environment.
4. Same as Recommendation 2 for airborne chemical contaminants.
5. Same as Recommendation 3 for airborne chemical contaminants.

6. Determine the "comfort zone" (in terms of dry bulb temperature, radiant temperature, air velocity, rate of change of temperature, humidity, etc.) in various hospital spaces.

7. The approach to specifying the new hospital ventilation standards needs to be determined; e.g., performance standards versus design criteria; CFM per square foot versus CFM per person versus air changes per hour; operational requirements as well as design; and inclusion of the fact that reduced ventilation rates are contingent on other control measures being in operation. This work would have to be conducted in close cooperation with several interest groups.

Appendix A

1978 International Working Conference

Advisory Panel

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Position Statements and Recommendations

The following statements were developed by the project staff from a review of the Conference transcript. They are divided into two categories:

1. Position Statements. These are positive statements made by one or more of the panelists that reflect the state-of-knowledge and were not seriously challenged by another panelist or an observer. Each is potentially the subject of a position paper in support of recommended changes in hospital ventilation standards.

2. Recommendations. These are suggestions for consideration as possible research projects.

AIRBORNE INFECTIONS

Position Statements:

1. 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. There are many studies which strongly indicate that some sound infections are due to airborne dispersal from identified carriers. However, other experiments studying 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, and that airborne infection should not be the limiting factor when establishing lower ventilation standards.

Recommendations:

2. 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 be further investigated.

3. More information is needed on the mechanisms by which gram negative organisms colonize in the upper respiratory tract; i.e., is air the source?

4. Information is needed on the mechanisms by which viruses are spread; i.e., viruses causing upper respiratory tract infections (myxo-, adeno-, rhino-viruses), rubeola, varicella-zoster and rubella. For example, 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.

HUMIDITY

Position Statements:

5. Although many older studies have shown that the mucus membrane dries out and the cleaning function disappears under conditions of low humidity, it was felt that the nose has a humidifying capacity sufficient to compensate for exposures to dry air and similarly that high relative humidity has no effect on respiratory function. This led to the conclusion that there is no physiological need to control humidity.

6. Studies to validate and extend Yaglou's early work have shown that humidity has little effect on body temperature and heat balance until maximum skin wettedness is reached. It was observed that humidity is not a comfort factor for healthy subjects in clean air.

7. However, it was further agreed that both very low and very high humidities can cause a variety of other difficulties (formaldehyde emission, skin scale shedding, increased numbers of house dust mites, condensation and growth of fungi on walls, static electricity, smoke odors, etc.) that require further study and will determine humidity range endpoints, vis-a-vis thermal comfort.

8. It was agreed that the use of explosive anesthetic gases is waning, eliminating the need to establish operating room humidity levels based on air explosion hazard.

Recommendations:

9. If humidity is allowed to float throughout the hospital (excluding special areas) within the wide limits such as 15 to 20 percent minimum and up to approximately 70 percent, then further studies need to be conducted

of the effects of humidity extremes on patients, furnishing and electronic equipment. With regard to low humidity, concerns include increased skin shedding; effects on electronic equipment which is highly subject to stray fields and static charges; and destruction of books and furniture due to the dryness of the air. At the high end of the spectrum, humidity problems include condensation of water vapor on cold surfaces and subsequent growth of allergenic microfungi; corrossion of metal furnishing and equipment; and increased formaldehyde emissions from resins in furnishing and building materials.

10. The relationship of allergenic mites and their ability to proliferate at different humidities needs further study.

ODORS

Position Statements:

11. There was a consensus that odors are usually a point source problem and should be controlled on that basis rather than setting basic ventilation rates to dilute odors below their thresholds. Hospitals have numerous odor sources of varying intensities, with dilution by outside air as the current major method of control. 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 dilution air, therefore, not impeding reduction of ventilation rates.

12. There was complete agreement that 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. Besides limited application for long range effectiveness, these compounds increase the airborne chemical contaminant load with materials about which little is known.

Research Needs:

13. Yaglou's work on ventilation rates needed to dilute odors needs

validation in the context of today's technology and cultural factors.

14. 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 Statements:

15. There was general agreement that the 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 air 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.

16. It was suggested that 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.

17. Only a small amount of outside air is needed to meet the basic physiological needs of patients.

Recommendations:

18. 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 activated carbon filters, but these would ordinarily not be necessary in regular recovery or administrative areas.

19. 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.

20. Research is needed to resolve the questions of toilet exhaust recirculation.

21. The feasibility of varying ventilation rates with activity over a 24-hour cycle should be studied. For example, is it necessary to exhaust kitchen areas 24-hours a day even when they are not in use?

22. Ventilation standards should be developed which would apply under emergency conditions of severe energy shortage.

CHEMICAL POLLUTANTS

Position Statements:

23. 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:

24. A suggestion was made that the same methodology as was used to arrive at the Ambient Air Quality Standards could be used to establish hospital pollutant/chemical contaminant standards.

25. It was suggested that the extent of hospital pollution from each of these sources 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 Statements:

26. 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:

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

GENERAL COMFORT

Recommendations:

28. The importance and usefulness of radiant energy should be studied.

29. The effects of air ions on patient comfort needs study.

MANAGEMENT

Recommendations:

30. The feasibility of upgrading the quality of the maintenance and housekeeping staff to involve them deeply in the matter of energy conservation needs study.

31. A study should be made of the quality of routine filter maintenance in representative hospitals.

32. The potential for energy conservation through proper operation of the physical plant should be carefully demonstrated.

33. Computerized energy management systems and there potential use in hospitals should be evaluated.

34. Energy audits should be taken in hospitals to determine where energy use can be curtailed.

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