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HOSPITAL VENTILATION STANDARDS AND ENERGY CONSERVATION: PROCEEDINGS OP THE 1978 INTERNATIONAL WORKING CONFERENCE

Author

Michaelsen, George S.

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HOSPITAL VENTILATION STANDARDS AND ENERGY CONSERVATION:

PROCEEDINGS OF THE 1978 INTERNATIONAL WORKING CONFERENCE

George S. Michaelsen,
Conference Chairman

SCHOOL OF PUBLIC HEALTH
UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA 55455

Roger L. DeRoos,
Principal Investigator

Kay Cady,
Assistant Editor

August 1978

Submitted to:

University of California
Lawrence Berkeley Laboratory
Berkeley, California 94720

Craig D. Hollowell,
Principal Investigator

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September 1978

Division of Environmental Health
School of Public Health
University of Minnesota
Minneapolis, Minnesota 55455

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PROCEEDINGS OF THE 1978 INTERNATIONAL WORKING CONFERENCE

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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1978 International Working Conference

HOSPITAL VENTILATION STANDARDS AND ENERGY CONSERVATION

Conference Proceedings

February 21, 22 and 23, IDS Center

Minneapolis, Minnesota

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APPENDIXES

Executive Summary

Mr. Robert S. Banks

The University of Minnesota School of Public Health, under contract to Lawrence Berkeley Laboratory, is examining the basis of current hospital heating, ventilating and air conditioning standards to determine if they can be relaxed based on criteria that do not compromise the health, safety and comfort of patients and staff and have acceptance of the health care community. This work 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.

One of the University's major tasks was 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 consideration of 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 four topics for the first two days:

- Infectious Agents: Role of Airborne Biological Agents.
- Physical Factors: Temperature, Humidity, Air Motion and Radiant Energy.
- Chemical Contaminants: Sources and Problems Arising Therefrom.
- Aesthetic Factors: Odors, Air Fresheners, Air Ionization, Stale and Fresh Air.

Each topic was introduced in a morning session with a prepared presentation by a panelist, followed in the afternoon with a discussion led by another panelist. The third day was devoted to developing the panelists' recommendations to the University.

A verbatim record of the entire proceeding was taken by a court reporter. This transcript, with a draft set of Position Statements developed by the University, was compiled into a Draft Proceeding (March 1978). This document was then sent to all panelists for review and comment.

The present document, the Final Proceeding, incorporates all feedback received from panelists, including a revised set of position statements. The transcript has been heavily edited to eliminate extraneous material, clarify the verbal presentations and provide a more cohesive organization. Nothing of substance, however, has been omitted.

Herein, the Conference material is organized somewhat differently to take advantage of the natural course of the discussions:

I. Infectious Agents
II. Physical Factors
III. Chemical Contaminants and Aesthetic Factors
IV. Final Discussion

The Position statements and Recommendations herein were developed by the University based on the Draft Position Statements contained in the Draft Proceedings, feedback from the panelists, and additional review of the edited transcript by the project staff. 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.

The Conference was advisory to the University of Minnesota School of Public Health and the purpose of this proceeding is simply to document the Conference, not to provide final recommendations on the part of the University as to either ventilation standards or research needs.

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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Foreword and Introductory Remarks

Professor George S. Michaelsen

The University of Minnesota School of Public Health sponsored an International Working Conference on Hospital Ventilation Standards and Energy Conservation, in the Gemini Room, IDS Center, Minneapolis on February 21-23, 1978. Overall, the objective was consideration of 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.*
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> *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 consideration to energy conservation....*
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> *The major task of the panel will be to review present standards for the design and operating 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:*
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> - *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 deliberations.

A verbatim transcript of the Conference presentations and subsequent discussions was taken. The major contributors were given an opportunity to review their portions of the transcript to correct any errors which might have occurred in the transcription and to clarify some of the discussions. This proceeding incorporates their review as well as extensive editing to remove extraneous material and was reorganized to present subject matter in a coherent fashion. Nothing of substance to the Conference was removed. The Position Statements and Recommendations represent the project staff's understanding of the panelist's recommendations, developed from review of the transcript. A draft was reviewed by the panelists, and their comments have been incorporated. In effect, the Position Statements and Recommendations could also be termed "State-of-Knowledge" and "Research Needs."

The Conference was advisory to the University of Minnesota, and the purpose of this document is to record its deliberations and recommendations It is but one step of many needed to arrive at final recommendations for ventilation standards and additional research needs.

Conference Welcome

Dr. Roger L. DeRoos

As principal investigator for this project, I welcome you on behalf of the University of Minnesota School of Public Health, to this International Working Conference on Ventilation Standards. Each of you has been invited not because of who you represent but because of your technical understandings and your professional judgment as related to the objectives of this project.

The Department of Energy, which has provided the support for this effort through the Lawrence Berkeley Laboratory, anticipates that the University of Minnesota will use recommendations that are generated at this Conference to provide a basis for consideration of what is already known that could lead to developing changes in hospital ventilation standards to conserve energy. It is also our intention to delineate further research needs and possible information gaps that could lead to further energy conservation through additional changes in ventilation standards.

There is little question that the United States has had an extremely energy intensive economy in both industrial and commercial sectors. 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 products, is directly responsible for our Project Independence: a broad multidimensional federal program designed to achieve energy self-sufficiency during the 1980s. Existing buildings are responsible for an estimated 35 percent of the nation's energy budget. Consequently, building

conservation measures are a priority objective for Project Independence. The Conference examines a segment of this building conservation concern: health care facilities.
Much attention has been drawn to the fuel saving measures for private dwellings and non-priority commercial and public buildings. Health care facilities are justifiably designated as priority users of natural gas, heating oil and other fuels. At the same time, 32 percent of American hospitals burn only natural gas under their boilers, a practice that may receive increasing scrutiny by local jurisdictions with responsibility for allocating this scarce fuel.

In 1976 there were approximately 36,776,000 million admissions to the 1,434,000 million hospital beds in 7,082 hospitals across the United States. This does not include nursing homes and other long-term health care facilities which also consume a significant portion of our nation's energy 24 hours a day, seven days a week. It has been estimated that hospitals consume approximately 15 percent of the energy used in commercial structures throughout the country, an equivalent of 400,000 barrels of oil a day. Approximately 30 to 50 percent of this energy is used for heating and another 10 to 15 percent for cooling. Therefore, measures to reduce energy consumption in health care facilities could have an impact on the nation's overall energy conservation.

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 no exception. It is estimated that more than 90 percent of the nation's hospitals were designed and constructed prior to 1973-1974, and are considered energy inefficient by today's standards. Therefore, the first major thrust for hospital energy conservation is that of implementing various engineering measures to reduce energy consumption, in other words, energy management.

However, not only have hospitals been virtually guaranteed an uninterrupted supply of fuel thus far, but there has also been considerable reluctance to lower present heating, ventilating and air conditioning (HVAC) standards because of the concern over a possible adverse impact on the health, safety and comfort of patients as well as staff. There is no question that hospital HVAC systems are designed to maximize the well-being of patients and staff, not minimize the consumption of energy.

In the past several years as we have examined the standards for heating and ventilating within hospitals we have tended to overlook the concern of energy conservation, thus, a second strategy is to systematically reassess hospital ventilation standards. The majority of these standards was established in the early 1960s or earlier and it is possible, in light of new information, that many are overly conservative. The purpose of this project is to explore possible energy conservation opportunities for heating, ventilating and air conditioning systems. Specific attention will be given to possible relaxation of standards to provide a further increase in energy conservation over that possible from hospital energy management programs alone. The objective of this research, therefore, is to re-examine heating, ventilating and air conditioning standards in the hospital to determine if they can be relaxed or restated in a direction to reduce energy demands.

SECTION I:
INFECTIOUS AGENTS

Dr. Claus O. Solberg
University of Bergen
Haukeland Hospital
Bergen, Norway
and
Dr. Anna Hambraeus
Assistant Professor
Department of Clinical Microbiology
Akademiska Sjukhuset
Uppsala, Sweden

Role of Airborne Bacteria Transmission

Dr. Claus O. Solberg

One is sometimes asked which group or which source of infection is the most important in hospital infections: direct or indirect contact infection, or contamination. This is difficult to answer. It reminds me of a sign on a wall behind a very busy American working in a travel agency, "Difficult things we solve immediately. Impossibilities take five minutes."

The difficulties are not easily solved in the field of infectious agents particularly when we have to evaluate the importance of airborne versus contact infection. Difficulties occur in this field because the route of infection differs from organism to organism and from one place to another depending upon what has been done to eliminate sources and to close avenues of transfer. It also differs for any one species of microbe and for any one place from time to time, depending on what sources are present and what phage type within the microbial species is prevalent.

Within the hospital, there are three areas where the importance of airborne infection has been studied: firstly, the surgical operating room; secondly, the ward areas, particularly for patients with respiratory tract infections and for newborns, and thirdly, the patient isolation room.

During surgery, in the so-called conventionally ventilated operating room, it has been well documented that *Staphylococcus aureus* can spread throughout the suite. This does not necessarily mean that these organisms cause infection. However, there are many reports in the literature concerning natural

outbreaks of wound infection due to airborne spread of *Staphylococcus aureus* during surgery. Ayliffe and Collins in 1967 studied 251 operations and monitored all personnel involved with these operations as summarized in Table 1.

Table 1. Reports of typical outbreaks of wound infection due to airborne spread of *Staphylococcus aureus*.

AYLIFFE AND COLLINS 1967 :	
NO. OF OPERATIONS	251
NO. OF INFECTIONS OCCURING IN :	
A) OPERATING ROOM	3
B) WARD	4
WALTER ET AL. 1963 :	
NO. OF OPERATIONS	169
NO. OF INFECTIONS	2

Seven patients were identified whose postoperative *Staphylococcus aureus* infections stemmed from an orderly who was the only one in the surgical room carrying the same phage type.

Walter and colleagues reported a similar event in 1963 in which two out of 169 patients developed postoperative wound infection following exposure to a carrier who was gowned and masked and remained on the periphery of the surgical room and

had no contact with other personnel and the patients. The route of infection was, in all likelihood, airborne since no other carrier of this specific phage type was found among the other operating room personnel. Identical organisms were also recovered from several environmental cultures, including the operating field.

These studies strongly indicate that a series of wound infections is due to airborne dispersal from an identified carrier. However, the reports do not establish the relative importance of this route of infection compared to other routes.

During recent years it has become generally accepted that positive pressure ventilation of the operating room with 12 to 15 air changes per hour is desirable for general surgery. At this ventilation rate the level of air contamination will usually lie between 100 and 300 bacteria carrying particles per cubic meter. With modern ventilation techniques, it's not difficult to achieve further reductions of 50, maybe 100 fold or even more. Several investigations have been performed in general surgery to examine whether a reduction of airborne bacteria in the operating room may result in a reduction of postoperative wound infection.

At Cincinnati General Hospital, a double blind study was was performed using ultraviolet irradiation (see Table 2). The study included five University surgical departments and was conducted over a two and a half year period in the early 1960s. A significant reduction in the number of airborne bacteria was observed down to 50 to 63 percent varying within the surgical departments when ultraviolet irradiation was used and the infection rate for so-called "refined clean" operations, like hernia operations, was decreased. However, the average overall postoperative wound infection rate was 7.4 percent when ultraviolet irradiation was used. In the control

when dummy irradiation was used there was a 7.5 percent infection rate. Therefore, it was concluded that ultraviolet irradiation was not effective in reducing the incidence of postoperative wound infection. This study and others indicate that the majority of infections was caused by the patients' endogenous flora. Resection of segments of the gastro-intestinal, genitourinary or respiratory tract is associated with a three to seven-fold increase in the postoperative wound infection rate compared to clean operations such as orthopedic surgery. This is most likely due to contamination with the patients' endogenous bacteria, which again means contact infection.

Table 2. Influence of ultraviolet irradiation on postoperative wound infection.
(NATIONAL RESEARCH COUNCIL 1964).

AIR CONTAMINATION	
CONTROL CONDITIONS (DUMMY LAMPS)	100 %
ULTRAVIOLET IRRADIATION	50 - 63 %
WOUND INFECTION	
CONTROL CONDITIONS	7.5 %
ULTRAVIOLET IRRADIATION	7.4 %

So, if there are many non-clean operations, the influence of airborne contamination on the infection rate may be completely lost in the overall infection rate. To avoid this disturbing influence of endogenous flora from the gastro-intestinal, genitourinary and respiratory tract, more recent studies concentrated upon clean operations such as orthopedic and cardiac surgery. Franco and coworkers published in 1976 a study (see Table 3) of the effect of laminar airflow systems and aspiration suits on airborne contamination and wound contamination (not infection) in orthopedic surgery.

Table 3. Effect of laminar air flow system and aspiration suits on airborne bacteria and wound infections in orthopedic surgery.

(FRANCO ET AL. 1976).

	LAF / AS	LAF	CONTROL
NO. OF CASES	37	40	30
MEAN C F U / ft^3 OF AIR AT THE ORIFICE OF SURGICAL WOUND (RELATIVE AIR CONTAMINATION)	0.06 ± 0.10 (1)	0.13 ± 0.34 (2)	1.55 ± 1.00 (25)
MEAN BACTERIA / WOUND CULTURE	77 ± 304	187 ± 359	15 ± 34
NO. OF INFECTIONS	1	3	0

The patients were divided into three groups: 1) the laminar airflow system (Federal Guidelines 209A for a Class 100 clean room) was in operation during surgery and aspiration suits were worn (37 patients); 2) the surgery was performed with the laminar airflow system in operation but no aspiration suits were worn (40 patients), and 3) surgery was performed without using laminar airflow and aspiration suits (30 patients). The number of airborne microorganisms at the orifice of the surgical wound (determined by slit-sampler plus tubing) was 10 and 25 times higher in the control group than in the LAF and LAF/AS groups, respectively. Wound cultures were obtained every 20 minutes during surgery using swabs. There was no significant difference in the mean number of organisms per culture among three groups, and accordingly no correlation between the level of microbial air and wound contamination in any of the cases in the three groups. Furthermore, different bacteria were nearly always cultured from the air and surgical wound during operation. Four infections occurred--all in the LAF or LAF/AS groups. In conclusion, wound contamination and infection seemed to occur by other than the airborne route of transmission.

Several investigations support these findings, as indicated in Table 4.

Table 4. Influence of bacterial air contamination in wound infection in clean surgery.

INVESTIGATION	TYPE OF SURGERY	INFLUENCE OF AIR-BORNE BACTERIA
Mc LAUCHLAN ET AL. 1976	HIP REPLACEMENT	NONE
IRWINE ET AL. 1974	——— " ———	NONE
SCHWAN ET AL. 1977	——— " ———	MINOR
CLARK ET AL. 1976	CARDIAC SURGERY	SOME
BLAKEMORE ET AL. 1971	——— " ———	SOME
CHARNLEY & EFTEKHAR 1969, 1972, 1973	HIP REPLACEMENT	SIGNIFICANT (?)

McLauchlan and colleagues, 1976, found no difference in infection rate (hip replacement) when surgery was performed in ultraclean and plenum-ventilated operating rooms. Irwine and coworkers, 1974, performed 100 hip joint replacements in a laminar airflow chamber and 100 in a conventionally ventilated operating room and found no difference in infection rate between the two groups. Schwan and coworkers, 1974, also indicated that airborne infection is not a major cause of infection in hip replacement surgery.

On the other hand, Clark and coworkers, 1976, and Blakemore and coworkers, 1971, have emphasized the influence of airborne bacteria on the incidence of septicemia and bacterial endocarditis in cardiac surgery. Charnley, 1973, the "world champion" in hip replacements with more than 6,000 operations--reported a decrease in infection rate between 1960-1970 from 7 percent to 0.5 percent. He feels that this reduction is due to operation in clean air ("greenhouse") - reduction to 1.5 percent - and measures taken to stop bacteria from penetrating

the surgical gown with a reduction to 0.5 percent. However, during the same period, Charnley also introduced other preventive measures: two pair of gloves instead of one pair; special surgical coats; better skin disinfection procedures, and most likely an improved surgical technique over the years.

It is evident that no hard statistical data are universally agreed upon that prove or disprove that clean air systems decrease the infection rate. However, it should be remembered that when the infection rate in orthopedic surgery in conventional operating rooms is as low as 1-2 percent, a further 0.5-1 percent reduction requires several thousand operations in order to demonstrate statistical significance.

HOSPITAL WARD INFECTION: AIRBORNE TRANSMISSION

Airborne transmission of infectious disease has often been demonstrated in hospital wards. Wells and Riley clearly demonstrated the importance of this route of transmission for tuberculosis. At the Veterans Administration Hospital in Baltimore, patients with open tuberculosis were admitted to a ward containing six single rooms. Air from the ventilating system of the ward was discharged through a large guinea pig chamber on its way to the outdoors. During the first two years of the experiment 71 guinea pigs developed turberculosis and the average time required to infect the animals was 10 days. Since one droplet nuclei containing tubercle bacilli gives rise to one tubercle in the animal lungs, the number of tubercle bacilli inhaled by the animals and the number in the air could be calculated. When the air was exposed to ultraviolet light before reaching the animals, no infection occurred.

In the days before chemotherapy of tuberculosis, many careful studies were made to calculate the air contamination

with tubercle bacilli by measuring the rate of conversion of the tuberculin test in nurses working in the wards. Usually, the tuberculin test converted to positive in 6-18 months. The volume of ward air containing an infectious dose (quantum) of tubercle bacilli was estimated from the volume of ward air breathed by a nurse during this time.

While the airborne route of transmission is clearly established in tuberculosis, the importance of this route of infection is not so obvious in other bacterial infections for example streptococcal and staphylococcal disease. However, there are some good experiments where the role of airborne versus contact transmission has been studied.

Mortimer, Rammelkamp and coworkers studied the spread of staphylococci to newborns (see Figure 1) using a room with eight bassinets: four bassinets airborne at one end of the room and four at the other end. A line was marked on the floor to separate the two groups. X_1 and X_2 indicate who were staphylococcal carriers, and AB (airborne) and T (physical transfer) indicate babies who were taken directly from the delivery rooms--non-carriers. The nursery was staffed with eight nurses. Four took care of the AB babies and four took care of the T and X babies without crossing the line on the floor.

The rate of transmission was 10 percent (16 out of 158 babies) for the AB babies; that is airborne transmission. In contrast, 43 percent (49 out of 126 babies) of the T babies became colonized, indicating that physical contact is of major importance for the spread of staphylococci. When the nurses washed their hands with hexachlorophene between handling the T and X babies, the carrier rate of the T babies dropped to 14 percent. It is concluded that airborne organisms account for a smaller proportion of staphylococcal transmission in a

nursery than transmission by contact. The latter can also be efficiently reduced by handwashing techniques. Similar experiments have been done with adults and the same conclusion was reached.

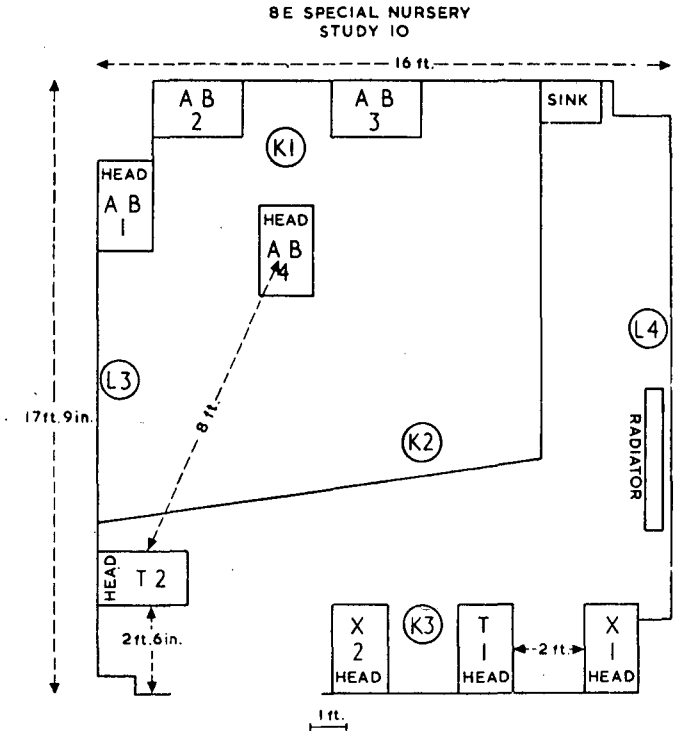

Diagram of study nursery. K 1, 2, and 3 and L 3 and 4 are locations of settling-plates. X 1 and 2 are bassinet positions of infant carriers ; T 1 and 2 and AB 1, 2, 3, and 4 are bassinet positions of " physical transfer " and " airborne " infants, respectively.

Figure 1. Spread of staphylococci to newborns.

It is well known that hospital cross-infection takes place with Mycoplasma species and several viruses as listed in Table 5, particularly within pediatric departments. Airborne spread of smallpox can take place over at least one to two floors and down long corridors. This was clearly demonstrated during the epidemic in Meschede, Germany.

Table 5. Viruses and Mycoplasma which infect the human respiratory tract.

VIRUSES AND MYCOPLASMA WHICH INFECT THE HUMAN RESPIRATORY TRACT

Viruses	Diameter (Microns)	Total No. of Types	Clinical Syndromes	
			Adult	Children
Myxovirus				
Influenza Virus	.08 - .12	A, B, C	URI	URI
			LRI	LRI
Parainfluenza Virus	.12 - .25	4	URI	URI
			LRI	LRI
Respiratory Syncitial Virus	.09 - .14	2	URI	URI
				LRI
Rubeola (Measles)	.10 - .20	1		LRI
Adenovirus	.06 - .08	44	URI	URI
				LRI
Picornavirus				
Enterovirus				
Coxsackievirus	.02 - .03	A - 24	URI	URI
		B - 6	LRI	LRI
Echo	.025	34	URI	URI
Rhinovirus	.018-.028	30	URI	URI
Reovirus	.02 - .03	3	URI	URI
Herpes virus	.12 - .18			
Herpes simplex			URI	URI
Varicella-Zoster Virus			LRI	
Cytomegalovirus				
Mycoplasmas (PPLO)	.125-.250			
Mycoplasma Pneumoniae (Eaton)		1	LRI	LRI
Mycoplasma Hominis		1	URI	URI

(URI - Upper Respiratory Tract Infection - Larynx and Above)
(LRI - Lower Respiratory Tract Infection - Below Larynx)
(1 Micron = 1/1,000 of a millimeter)

Epidemics of measles and German measles have also been reported from several hospitals. However, the part played by airborne transmission in most viral infections is far from clear. Wenzel and coworkers, 1977, at the Virginia Medical Center studied the transmission of upper respiratory tract infections caused by viruses using an experimental model similar to the one by Mortimer and coworkers. A one to four-year-old child with an upper respiratory tract infection was placed in one corner of a four-bed room and three other children with no virus infection in the remaining corners. Only 3 percent of the children developed infection with the same strain as the index patient. The conclusion was that isolation of patients with upper respiratory tract infections was not necessary. The same conclusion has also been reached in other studies.

In other studies it has been demonstrated that parents, visitors, and especially hospital personnel shedding viruses are suspect as the source of upper respiratory tract infections with viruses. Isolation of patients with upper respiratory virus infections in rooms with separate ventilations has therefore, been regarded as unnecessary. Instead, efforts might be directed at interrupting hand to hand or large droplet spread of viruses from medical personnel and visitors shedding the virus. Frequent hand washing and surgical masks may be of significant importance in preventing infections to small children when they are hospitalized.

The part played by airborne transmission in most viral infections is far from clear. More studies like the one by Wenzel and coworkers are strongly needed. Today, similar studies can more easily be done due to the availability of good virus culture techniques.

Protection of highly susceptible patients, for example immunodeficiency patients, against both viruses and bacterial infections can, however, be achieved by the combined use of strict aseptic technique and isolation in laminar airflow rooms. This has been nicely demonstrated in dummy experiments at the University of Minnesota and also in patients in Minneapolis, Copenhagen, Leyden and elsewhere.

The role of lower respiratory tract infections in relation to the overall prevalence of hospital infection ranges from 15 to 35 percent. Many of these infections are caused by gram positive cocci, but the majority are caused by gram negative rods. The major causes of these hospital acquired infections are aspiration of fluid from the pharynx during anesthesia, intoxications and all kinds of conditions when the cough reflex is depressed; introduction of bacteria into the respiratory tract by various equipment such as humidifiers, nebulizers,

and respirators, and inhalation of small particle aerosols from the upper respiratory tract or from the air. Again the role of the various routes of infection is unknown but varies from place to place and from time to time.

As I see it, one of the most important gaps in our knowledge about hospital infection is our ignorance of the dose of microorganisms needed in order to establish clinical infection. Another gap is our lack of knowledge about why people vary so much in their ability to disperse their organisms into the air. I would therefore like to present to you a study we did some years ago to find out why staphylococcal carriers differ so much in their ability to disperse their organisms into the air.

During a 15-month period bacteriological samples were obtained on three consecutive days from the nose, throat and perineum of 2,614 patients admitted to a medical department in order to detect staphylococcal carriers. Among these carriers 175 were randomly selected and the number of staphylococci in the vestibule of the nose, throat, axillae, hands, skin of the abdomen and perineum was evaluated once daily on two consecutive days. The ability of the patients to disperse their organisms into the air was estimated by isolating the patients in special test chambers for two hours. During this period the bed was made by a sterile-dressed nurse. The staphylococcal air contamination was measured during the period using slit samplers.

In the 175 patients, marked differences in staphylococcal dispersal were observed, ranging from less than 20 to more than 900.000 CFU in the two-hour period (see Figure 2). The counts were distributed in a log-normal fashion. Fifteen percent of the patients dispersed more than 10,000 CFU.

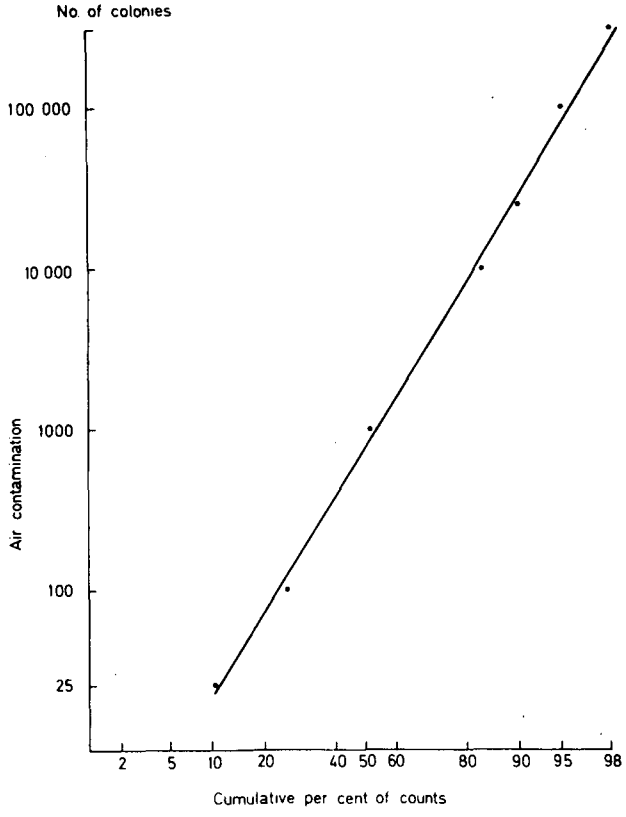

Figure 2. Dispersal of staphylococci from patients.

Relatively few staphylococci were liberated into the air during the first hour of the test when the patients stayed in their beds, talked, sat reading or walked around in the chamber. More than 90 percent of the staphylococcal air contamination resulted from the making of the beds. These results support the view that staphylococcal carriers disperse their organisms into the air indirectly via their clothes and especially their bedclothes and that transmission of staphylococci from carrier to recipient seldom takes place by means of droplets or droplet nuclei expelled from the nose and throat.

Patients with staphylococcal-infected lesions (see Figure 3) were among the heaviest dispersers, with four patients

dispersing more than 100,000 CFU in the two-hour test.

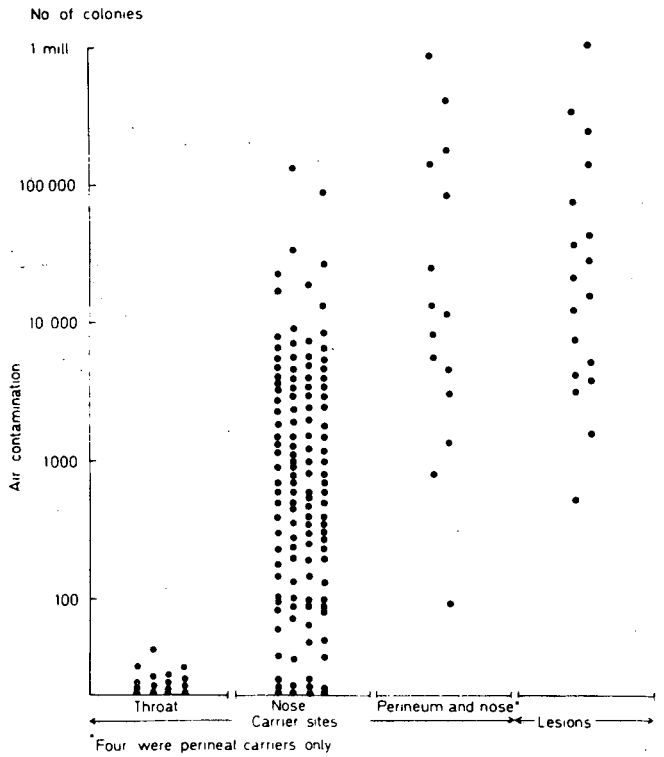

Figure 3. Staphylococcal dispersal by carrier sites and lesions.

Very few staphylococci were liberated by the throat carriers. The air contamination by the nasal and combined nasal and perineal carriers differed markedly from less than 20 and 100 to more than 100,000 and 800,000 CFU, respectively.

So, what was the reason for this huge difference in staphylococcal dispersal? By comparing the result of air contamination with the number of staphylococci isolated from the various skin areas (see Figure 4), we found that the number of staphylococci isolated from the hands of the nasal carriers varied from less than 10 to more than 2 million CFU. Only small numbers of staphylococci were isolated from other skin areas. A close correlation (r=0.87) was observed

between the number of staphylococci liberated into the air and the number isolated from the hands.

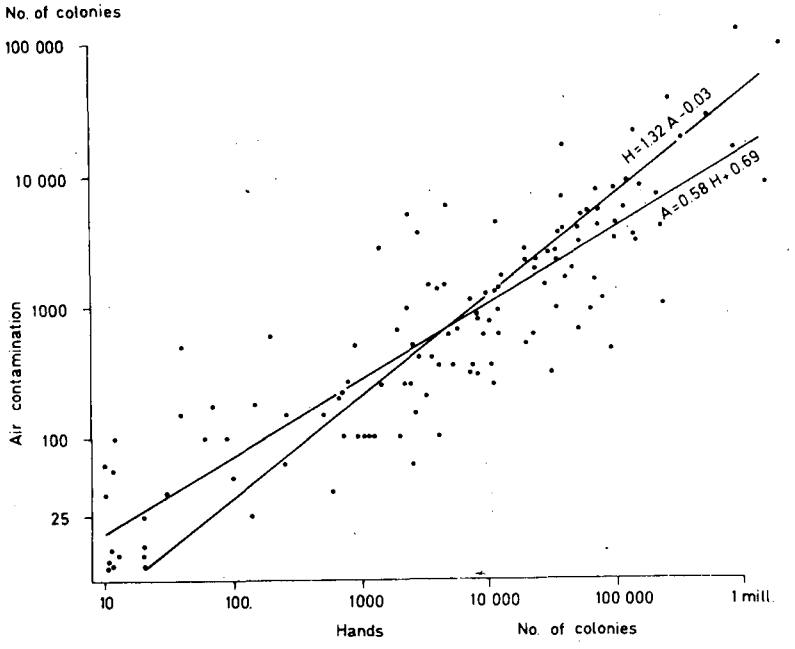

Figure 4. Comparison of the result of air contamination with the number of staphylococci isolated from various skin areas.

As for the perineal carriers and the patients with skin lesions, the staphylococcal air contamination increased within wide limits with increasing amounts of staphylococci on the skin. staphylococcal throat carriers had very few or no staphylococci on their skin, and they dispersed very few or no organisms into the air. Accordingly, there is a close correlation between the number of staphylococci on the skin and the number dispersed into the air.

Examination of the staphylococcal particles liberated into the air revealed that the bacteria were attached to skin scales as evidenced in Figure 5. Using micropipettes the organisms could be transferred from the skin scales to a culture medium, and the phage type was always identical to the one in the skin

samples from the same patient. Our observations support the view that dissemination of staphylococci into the air is due to a continuous desquamation of skin scales carrying cocci.

Figure 5. Bacteria attached to skin scales.

How can the staphylococcal dissemination be reduced? We treated staphylococcal nasal and perineal carriers once daily three days with hexachlorophene disinfection of their nasal vestibule, hands and perineum. During treatment a marked reduction (see Figure 6) was observed in the number of staphylococci on the various skin areas and the number liberated into the air. The same treatment was introduced in a surgical department. This resulted in a marked reduction in staphylococcal air contamination and carrier rates. The postoperative wound infection rate was reduced from 8.1 to 2.1 percent.

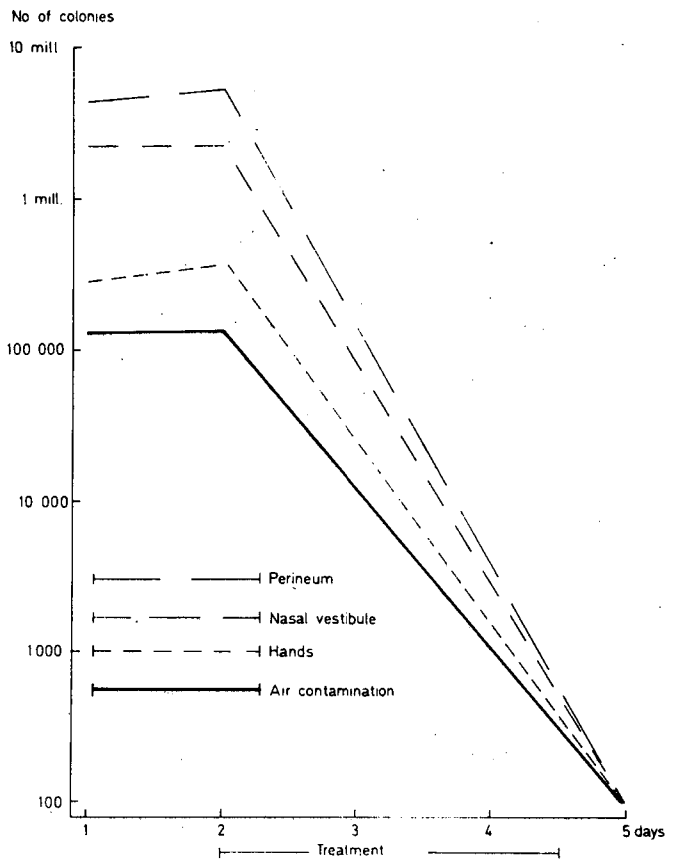

Figure 6. Reduction of staphylococci on skin areas; number liberated into the air.

Similar studies as this one to measure the dispersal of staphylococci can be performed for other bacteria and viruses in order to find out which persons are heavy dispersers and how this dispersal might be reduced.

Thus far, researchers have been working more on a qualitative level. In the future we should try harder to: 1) measure the microbial load to which the patient is exposed and the actual rate at which the microbes reach him; 2) grade the virulence of the pathogens, and 3) discover quantitative indices of patient susceptibility. Then we may be able to assess the role played

by various factors in the etiology of infection and also the airborne route of infection.

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Effect of Ventilation on the Transfer of Airborne Bacteria

Dr. Anna M. Hambraeus

Two investigations have been made in Uppsala in order to estimate the effect of ventilation on the transfer of airborne bacteria. It is quite clear that the situation in a hospital is so complex that in most cases it is very difficult to draw any valid conclusions concerning the effect of ventilation on infection rates.

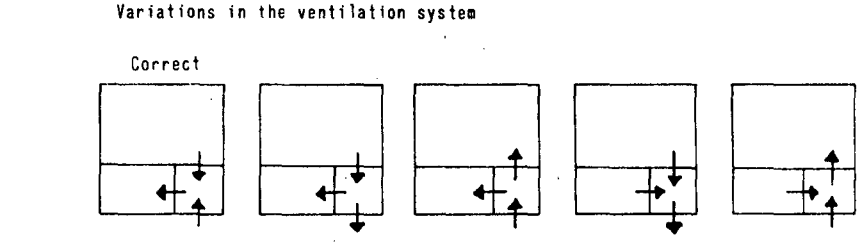
There is often a demand for more and more air changes per hour but at the same time, there is very little knowledge about the efficiency of the existing ventilation system. The problem has been to find a suitable experimental model with which ventilation can be tested. The most common way is to use tracer gases. The results from such investigations cannot be directly applied to transfer of bacteria carrying particles. Bacteria are usually carried on skin scales with a mean sedimentation rate of 0.3 meters per minute.[12] This adds to the disappearance of bacteria from room air. To study the effect of ventilation on particles, dispersal of bacteria has been used. There are objections to the widespread dissemination of bacteria in hospitals, however harmless they may seem to be. The distribution of recognizable strains from patients has been studied but it is very complicated and time consuming. Fluorescent tracer particles have been used but this technique is also rather complicated.[2]

In 1972 Foord and Lidwell introduced a particle tracer method that was quite simple to handle.[7] Particles are produced by supplying a potassium iodide solution to the spinning disc. By varying the concentration of the solution it's possible to have

particles with different sedimentation rates. The particles are then collected by drawing the air through a membrane filter. The filter is stained with palladium chloride and dark brown spots of palladous iodide are formed.

A theoretical analysis of the efficiency of isolation against airborne particles for a variety of ventilation systems was also prescribed by Lidwell.[7] We have used the potassium particle tracer in an isolation ward for burn patients and in an operating unit.[3,5] For these experiments we chose particles with a sedimentation rate of 0.3 meters per minute. The results found in the isolation ward were also compared with the theoretical analysis. In both units the transfer of bacteria carrying particles was also investigated and the infection rates were followed.

The isolation ward had six patient rooms with airlocks. The ventilation in the rooms was about five air changes per hour. If functioning as designed, a small amount of air was drawn from the room and from the corridor into the airlock and extracted from there (see Figure 7). A simple smoke test, however, showed that the ventilation did not function as designed. There was often an airflow from the room into the passage, or from the passage right into the room. In the experiments the particle transfer from room to room was studied for correctly ventilated rooms as well as for rooms with incorrect ventilation. An experimental activity of one walk from the room to the corridor was performed every second minute. The results are presented as the ratio between the number of particles in the source room to that in the receiving room. The experiments had to be performed in two steps for technical reasons (see Figure 8). The transfer from room to room is calculated from these experiments. The normal activity in the ward was about one-sixth of the experimental activity and the alpha values have been corrected according to this.



Room No					
1	30	2	-	-	-
2	24	8	-	-	-
3	8	23	1	-	-
4	15	9	2	4	2
5	15	17	-	-	-
6	19	2	11	-	-
No obs.	111	61	14	4	2

→ direction of air flow

Figure 7. Variations in ventilation systems.

Different ratios acquired from experimental systems

$$\alpha' = \frac{\text{Concentration in source room}}{\text{Concentration in the passage}}$$

$$\alpha'' = \frac{\text{Concentration in the passage}}{\text{Concentration in the room}}$$

$$\alpha = \frac{\text{Concentration in the source room}}{\text{Concentration in another room}}$$

Figure 8. Ratios acquired from experimental systems.

There was no measurable transfer of particles when there was no activity. With normal activity the ratio between the source room and the receiving room was 3.4×10^5 when the rooms were correctly ventilated and 10 times less when the source room was incorrectly ventilated but the receiving room was correctly ventilated as indicated in Table 6.

Table 6. Particle transport in a correctly ventilated room, incorrectly ventilated source room and correctly ventilated receiving room.

Room to room transport of particles
assumed concentration in source room 1 particle/l.

	Correctly ventilated rooms	"Source room" incorrectly ventilated Receiving room correctly ventilated
α (no activity)	$>10^9$	$>10^9$
α ("normal" activity)	3.4×10^5	4.4×10^4
particle concentration in the receiving room	3×10^{-6} c.f.u./l	3×10^{-5} c.f.u./l
inhalation of 1 particle	every 3rd week	every other day
sedimentation of 1 particle onto 1/3 m^2 of body area	every other day	every 5th hour

Assuming one bacteria carrying particle per liter in the source room, this is a very high value, a patient in the receiving room then would risk to inhale one particle every third week, if the rooms were correctly ventilated, and one every second day with a faulty ventilation. The corresponding sedimentation onto one-third square meter of body area would be one particle every other day, or one every fifth hour if the rooms have faulty ventilation.

The values for airborne transfer correspond very well with the theoretical calculations. We thought that the airborne transfer could not explain the high rate of exogenous colonization

which was 60 percent. Therefore, we also studied the transfer of staphylococci unique for one patient. This was done every day when a single disperser was present in the ward. During a two-year period this occurred on 60 days. The transfer of the staphylococci was at least 10 times that found for tracer particles. From this we drew the conclusion that staphylococci were transferred by a route other than air currents. A detailed study of the nursing procedures showed that the dress worn underneath the protective gown was heavily contaminated with bacteria after nursing an infected patient. These bacteria were then redispersed in another room in spite of the fact that the nurses used different gowns in each room.

The transfer of staphylococci bacteria via clothes was quantified in nursing experiments.[4] The experimenter was dressed in a dress earlier used by a nurse underneath a protective gown when nursing a patient. On top of the dress the experimenter had a sterile cotton gown. A volunteer dressed in a sterile cotton gown was nursed and the nursing procedure took 25 minutes. During this time air was sampled and after the nursing period, the dresses and the sheets were investigated for the real burn patient's *Staphylococcus aureus*.

In Table 7 the transfer of particles and bacteria is summarized. As earlier, I have assumed a concentration of one particle per liter in the source room. The first row shows the transfer of airborne tracer particles at an average ventilation. If staphylococci were transferred by air current only the risk for inhaling one particle carrying staphylococci would be one every fifth day. But in reality, the risk was one every third hour. During a 25 minute nursing period, a patient might inhale one particle carrying staphylococci every third minute. Several volunteers were colonized during these nursing experiments.

Table 7. Summarization of the transfer of particles and bacteria.

	Transfer of particles assuming a concentration of 1 particle/l in the source room		Max transfer during a nursing experiment (25 min)	
	Airborne tracer particles	Staph.aureus-carrying particles	Airborne	Directly to the model patient
	Average vent	Arithmetic mean values		
Particles per l in a receiving room	1.4×10^{-5}	5.2×10^{-4}	3.6×10^{-2}	
Inhalation of 1 particle	every 5th day	every 3rd hour	every 3rd min	
Sedimentation of 1 particle onto 1/3 m^2 body area	every 12th hour	every 19th min	every 1/2 min	300 c.f.u./ 1/3m^2 in 25 min

Sedimentation of one particle onto 1/3m^2 body area would occur every twelfth hour for airborne particles and every nineteenth minute for staphylococci. During a single nursing period the patient might receive 300 colony forming units. Experimental infections of the skin performed by Marples and colleagues shows that 400 cells of *Staphylococcus aureus* is an infectious dose when the upper layer of the skin has been removed by tape.[11] Thus, the direct transfer during nursing may well represent an infectious dose. The situation in a burns unit may be extreme. However, investigations by Lidwell in medical wards has given the same results.[8] The discrepancy between airborne particle transfer and transfer of staphylococci has been obvious. The rates of nasal acquisition were also uncorrelated with the extent of particle transfer.[10]

The problem in the burns ward might be solved by using better protective gowns. When we changed nursing routines so that not only the protective gown, but also the dress worn underneath it was discarded after each nursing of a patient, the time of

the first exogenous colonization was delayed from the sixth day to the fourteen day.[13] The investigation in the operating ward was set up in a similar way with an attempt to compare experimental results with clinical observations. Figure 9 shows the layout of the central operating ward. Each room has an anesthetic room and two rooms share an exit area.

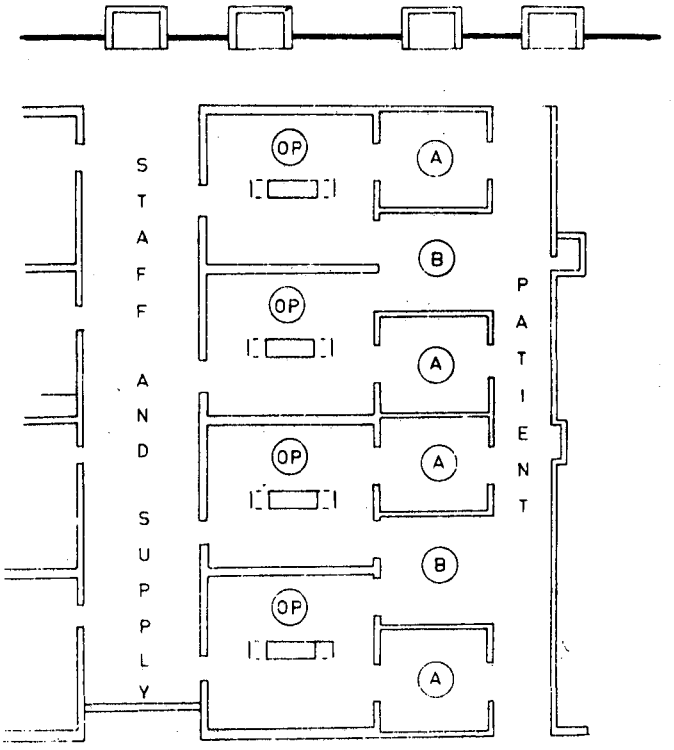


Figure 9. Layout of the central operating ward.

There are two types of ventilation in the operating rooms. Some have conventional ventilation with about 20 air changes per hour and a few have a type of zonal ventilation. The clean air inlet is just above the operating table as illustrated in Figure 10. This system provides the central air of the room with clean air corresponding to 80 air changes per hour. The risk

of transfer of airborne particles from areas outside the operating room to the operating room was calculated using the potassium ion spray method. As earlier, the experimental activity was one door opening per minute.

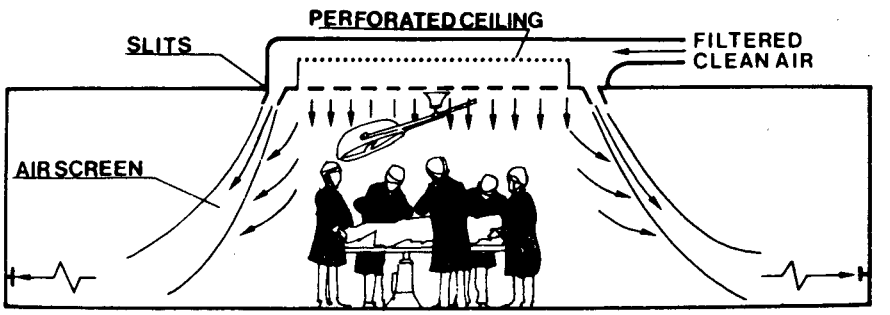


Figure 10. Clean air inlet above the operating table.

Figure 11 shows how many airborne particles were needed to get one particle into the operating room. From the anesthetic room and staff corridor, one particle out of approximately 2,000 slipped into the operating room. To get one particle from one operating room to the other via the exit area, which is the shortest way, it was necessary to have a level of 800,000 particles in the source operating room. Under normal conditions the number of door openings, though high, was not quite as high as under the experiments and the level of airborne particles was below 100. This means that a person would need to spend about 20 years in an operating room to risk inhalation of one particle from another operating room.

Of greater interest than the transfer from the outside into the operating room is the situation inside the operating room itself.

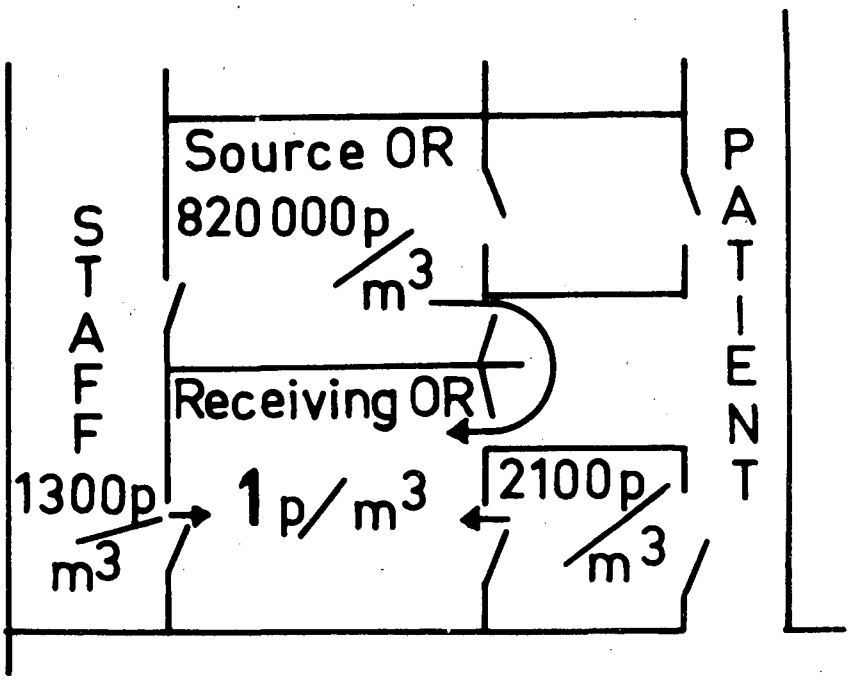


Figure 11. Number of airborne particles needed to get one particle into the operating room.

In the conventionally ventilated operating room the distribution of tracer particles as well as of particles generated by humans was even. In rooms with zonal ventilation the concentrations of tracer particles was about one-tenth in the center, as compared to that evidenced in the periphery. When particles were generated by humans, the difference was less, about one-half in the center compared to the periphery. When real operations were studied in some rooms with zonal ventilation the concentration of bacteria carrying particles was about half in the center.

Table 8 summarizes observations from 10 operations performed in rooms with conventional ventilation and 10 operations performed in rooms with zonal ventilation. The number of door openings was high with less than two minutes passing between each door opening. The number of people present at each

operation was also high with a mean value of 13 to 14. During these 20 operations, which were observed during a one-month period, 200 different people were present at the operations. The ventilation had been shown to be sufficient to prevent any greater transfer of paticles by air movements such as door openings.

Table 8. Summary of operations performed in rooms with conventional ventilation and zonal ventilation.

The effect of ventilation on air contamination

Comparison of activity and airborne contamination in operating rooms with zonal ventilation and operating rooms with conventional ventilation

	Zonal ventilation	Conventional ventilation
Mean length of operation	80 min	90 min
Minutes between door openings (mean value)	1.4	1.2
No. of people present (mean value)	13	15
Total number of bacteria		
mean of all samples	46.3 cfu/m^3	74.4 cfu/m^3
mean of means/operation	48.9 cfu/m^3	70.9 cfu/m^3
No. of Staph. aureus mean per operation	0.03 cfu/m^3	0.24 cfu/m^3

In spite of the varying number of people present, the level of air contamination was low, about 50 cfu/m^3 in rooms with zonal ventilation and around 75 cfu/m^3 in rooms with conventional ventilation. With the sampling method used it was not possible to catch minor changes in air contamination due to one or two extra people walking in and out. This is due to the high die-away rate one has even in rooms with conventional ventilation.

It is quite clear though that one extra person means an extra source of air contamination. From the experimental measurements of bacteria carrying particles generated by people, it was possible to calculate how the number of people effected the level of air contamination at different ventilation rates (see Table 9).

Table 9. Influence of staff density and ventilation on air contamination in the

Influence of staff density and ventilation on air contamination in the operating theatre

No. of persons present	Air turnover per hour				
	0	10	20	80	600
1	38*	13	8	2	0.3
5	188	67	41	12	1.7
10	375	135	82	25	3.5
15	563	202	123	38	5
20	750	269	164	49	7

* The effect of sedimentation on bacterial elimination has been included in the figures assuming a sedimentation rate of 0.3 m/min.

The level of air contamination was 41 cfu/m^3 in a room with 20 air changes and five people present. The calculated value for 10 people was 82, which is close to what we found during operations.

During a three-year period almost 3,000 patients were included in a prospective study. The postoperative infection rate was 9 per cent. For clean operations it was 3.4 percent and for infected or dirty operations it was 9.1 percent. For patients with risk factors the rates were considerably higher (see Table 10).

Table 10. Frequency of wound infection in different wound classes.

Frequency of wound infection in different wound classes

Wound class	Infected		Risk patients		No risk	
	Total No.	%	No.	% inf.	No.	% inf.
Clean	2,478	5.3	987	8.2	1491	3.4
Clean-contaminated	320	22.5	239	26.8	81	9.9
Contaminated	131	33.6	121	35.5	10	10.0
Infected or dirty	42	47.6	31	61.3	11	9.1
Total	2,971	9.0	1,378	15.0	1593	3.8

These findings are consistent with those in most investigations of this kind.

The mean number of air contaminants was the same in operations that later developed an infection as in those that did not (see Tables 11,12).

Table 11. Mean number of *Staphylococcus aureus* during different operations with and without wound infection.

Type of operation	Staph. aureus cfu/m^3		
	Wound inf.		
	-	+	Aureus inf.
Gastrointestinal	0.16	0.21	0.22
Cholecystectomy	0.14	0.11	0.08
Renal	0.17	0.34	0.68
Osteotomy	0.14	0.10	0.09
Open fracture	0.12	0.17	0.22
Closed fracture	0.17	0.12	0.12
Arthrotomy	0.13	0.11	0.35

Table 12. Mean number of bacteria during different operations.

Type of operation	Postoperative infection, %	Tot bact cfu/m^3 Wound infection -	+
Gastrointestinal	22.0	40.3	38.5
Cholecystectomy	7.9	41.9	38.8
Renal	11.0	45.2	44.5
Osteotomy	5.0	44.9	38.8
Open fracture	10.8	35.1	42.5
Closed fracture	4.6	37.0	34.4
Arthrotomy	2.3	31.3	35.2

In an overall analysis other factors were more important than the level of airborne contamination. As *Staphylococcus aureus* is typable so that it is possible to differentiate between endogenous and exogenous infections and as we especially looked for *Staphylococcus aureus* in the air, we analyzed these infections a little more. In all we had 76 *Staphylococcus aureus* infections which was roughly 2.6 percent; 44 of these were exogenous and could have been acquired during operations. In 23 of the cases, the strain was present during the operation. In 18 cases, the strain was found in the upper respiratory tract of staff members and in five of these cases in the air as well. In five cases it could only be found in the air.

The counts were low most of the time and there was no difference between mean counts during operations that later developed *Staphylococcus aureus* and those that did not.

However, we had a broadcasting episode with one strain that was found in a concentration of over 3 cfu/m. Two infections were caused by this strain which we believe was dispersed by an anesthetist. Thus, these infections may have been airborne indicating that there is a critical level for airborne *Staphylococcus aureus*. The disturbing presence of untraceable *Staphylococcus aureus* once more made us focus on clothes-borne bacteria. In an investigation of the surgeon's gowns we found that they were quite often contaminated after the operation and not with the surgeon's own staphylococci nor with staphylococci traceable to people at the operation, but with other staphylococci that the surgeon had probably picked up on his clothes during the day.[6] These could be transferred through the gowns to the patient. It is doubtful that the transfer of bacteria from the surgeon's gown to the patient can be eliminated by ventilation. A possible approach in order to minimize exogenous infections in clean operations may be demanding tightly woven gowns before demanding extreme ventilation systems.

We have made a number of operations with total body exhaust gowns and controls without gowns in rooms with zonal ventilation in hip replacement surgery only. Preliminary results on some 30 operations in each group show that when ventilated gowns were worn, the number of airborne bacteria was about one-fourth of that found when conventional clothes were worn. These results are consistent with that found experimentally.[14]

In summary, the conditions that ventilation does affect are airborne transfer of bacteria and the level of airborne contamination. Whether or not ventilation affects infection rates depends on the relative importance of the airborne route of transfer to other routes in a given situation. In both units studied the ventilation was, in most cases, kept at a level required for reasons other than prevention of infection

such as odor, temperature, and anesthetic gas toxicity. Yet, its effectiveness from a bacteriological point of view was far from utilized. At least one route of transfer was more important than airborne and far more difficult to control. There is a need to assess the level of air contamination which will reduce transfer of infection by the airborne route to below that due to other routes. As we are able to control these, our expertise in air control will become more rational and economic.[9]

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Infectious Agents: Discussion

DR. SOLBERG: When you introduced gowns or aspiration suits, did you experience a decrease in the number of bacteria carrying particles in the air?

DR. HAMBRAEUS: Yes.

DR. SOLBERG: Did you also measure the wound contamination with the bacteria?

DR. HAMBRAEUS: Yes. The influence of aspiration suits on wound contamination was not as clearcut as that on air contamination. We did exactly the same investigation in two hospitals in Sweden, one in Uppsala and one in Huddinge. We introduced total body exhaust suits in both of these hospitals and as I was working in one hospital at one time and in the other at another time the studies could be made in a similar way. We measured air contamination and the contamination in wound washouts.

DR. SOLBERG: Wound washouts?

DR. HAMBRAEUS: The air contamination was reduced to the same degree in both hospitals but in one hospital, no bacteria were found in wound washouts when total body exhaust gowns were used. In the other hospital there was no difference between wound washouts bacteria, whatever gown was used. So in that hospital there is a transfer of bacteria to the operating wound that does not seem to be airborne.

DR. SOLBERG: I think it is very important in future experiments not only to measure air contamination but also wound contamination and try to identify the bacteria. In recent years, this has been done by Dr. Raahave in Copenhagen. He and his coworkers used special pads applied to the wound

sites. After wound application for 20 minutes the pads were shaken in flasks containing nutrient medium and the number and type of bacteria determined. Nearly all wounds were contaminated with bacteria and there seemed to be a correlation between the number of pathogenic bacteria in the wound during surgery and the postoperative wound infection rate. In the future, studies like that should be done more often because I think we have to measure not only air contamination, wound contamination and the frequency of postoperative would infection but also to identify the bacteria in the air and wound samples and correlate the results to the postoperative wound infection bacteria.

MR. MICHAELSEN: Are you then assuming that the wound infection is from the air?

DR. SOLBERG: Nobody can really tell. Many investigators assume that when you cut through the epidermis many bacteria might come into the wound from the edges. Airborne contamination is very hard to prove, but I think that's the way we have to go, not only in one study, but in several.

DR. HAMBRAEUS: But at present, there is a multicenter study going on engaging about 16 hospitals in England, four in Sweden and some in Norway.

DR.HAMBRAEUS: In total hip replacement surgery wound and air contamination and infection rates are studied. Comparisons are made between operations performed by the same team in clean air with total body exhaust suits and those performed in conventional operating rooms. The results seem to be that in any setup the infection rate is going down during the study.

PARTICIPANT: Some years ago we tried sampling with a typical surgical procedure with the surgeon first performing the procedure in an undisciplined way and then repeating the same procedure under a highly disciplined condition. As I recall there was a marked difference in air quality in the immediate vicinity of the wound.

PARTICIPANT: The difference was basically in the ambient air around the patient and the conclusion with everything else being held equal was that activity was a major contributor to a higher bacteria count and with reduced activity the counts were lower.

DR. SOLBERG: As Dr. Hambraeus has shown, the less people entering the area, the better.

DR. HAMBRAEUS: To standardize has been a major problem because it's difficult to make a double blind study with body exhaust suits. We have tried and finally succeeded in having the same discipline in both kinds of operations.

PARTICIPANT: One of the best studies that's been done to try to differentiate whether the organisms in the wound come from the skin or from the air is work that Smilie and McLauchlan did in Aberdeen. They used a plastic isolator where the patient was essentially totally removed from the environment. As I recall they concluded that a substantial percentage of the contaminants came from the patient's skin as opposed to the air.

DR. SOLBERG: Sure, I don't know whether it's proven, but most people believe that contaminants come from the edges of the wound. There are some studies now where surgeons not only use pads, or suck up the wet sides of the wound, but they also try to cut out parts of the subcutaneous tissue, homogenize it and cultivate it to see whether that could give an even better indication than only using pads.

DR. ULRICH: One of the problems with skin contamination is that the bacteriology of human skin is not a surface phenomenon alone. The indigenous flora develops and is essentially a part of us. The organisms develop in the ducts of the sebaceous glands and are pushed to the surface largely thorugh the hair follicles. Peeling studies through 20 layers of skin cells, and after removing the surface layers, produces a constant quantification of the bacteria. The tapes have certain patterns that develop and these relate to the active follicle sites. No matter how

much the surface of the skin is scrubbed, the deep population cannot be controlled. In fact, it should not be destroyed as it's part of our own normal defenses.

DR. SOLBERG: But aren't those bacteria that are found further down in the epidermis, usually apathogenic?

DR. ULRICH: They are actually *Staphylococci dermatitis*, diptheriods and propionic bacteria. There have been studies done by other investigators to show that when infections appear to take place endogenously, they are milder than when the organism has come from an exogenous source. In other words, we have learned to live with our microbial flora.

DR. SOLBERG: In hip replacements some infections occur after one month, even two months after the surgery. Infections which develop that late are often caused by low virulent bacteria and I wonder whether if the bacteria colonizing the deeper layers of the epidermis, might be the cause of these late hip infections.

DR. ULRICH: Possibly.

DR. HAMBRAEUS: It's difficult to say whether it is from the members of the operation team, or from the patient himself without a typing system.

DR. ULRICH: In abdominal surgery even if the bowel is only pricked with a needle, very large numbers of gram negative bacteria are found in the abdominal cavity that have been pretreated with antibiotics. However, the number of patients that have developed infections is exceedingly small, as the endogenous organisms can be controlled.

DR. SOLBERG: We used to say that you can spit in the abdomen but can't look into a knee or a hip joint without getting an infection.

DR. ULRICH: Mucous membranes are pretty resistent to infection.

PARTICIPANT: In the discussion on ventilation, I get the impression we are discussing the total air exchange rate of the supplied air into the occupied space and not necessarily the amount of air that would be used for dilution, in other words, outside air. For instance, I think there was a slide shown by Dr. Hambraeus that indicated 600 air changes an hour which would be reasonable for the total air supply change rate. Only about five of these air changes per hour would be what we normally consider ventilation air. There are two mechanisms working with the dilution factor: 1) dilution between space, and 2) dilution exterior to the space. Is there any evidence from an infectious standpoint as to the relationship between actual ventilation and supply air exchange and the infection rate?

MR. MICHAELSEN: I was wondering, Dr. Ulrich didn't you come close to that in the recirculation study?

DR. ULRICH: I think what he is talking about was effective ventilation rate.

PARTICIPANT: Correct.

DR. ULRICH: And the effective ventilation rate depends on the system in use. The effective ventilation rate in a turbulent system is less than in a straight flowthrough system.

PARTICIPANT: Let me give an example. In the proposed changes to Hill Burton there are two types of air exchange that would be acceptable in the operating room. If recirculation was used we would need 25 air changes an hour, five of which would be outside air or what typically we would call ventilation air, using the standard definition for ventilation air. If we use 100 percent outside air, then the total air supply can be lowered to 15 air changes per hour according to the proposed modification. So there is a real physical difference. At the same time I suspect we would see a difference as far as infection.

DR. ULRICH: There is a difference in the number of organisms depending upon the source of air. From the Anderson sampler studies we have found that when you are using 100 percent outside air, the efficiency of the filters is less largely due to the fact that the particle size of outside air is smaller than those generated within the surgery itself. We have a more efficient system with recirculation single pass systems.

DR. MICHAUD: I think the standard referred to also says that with the 25 air changes, of which five are outside, you need a 90 percent filtering mechanism within the system. In your testing, what type of filtration mechanism was used, say in the 20 air change room, as opposed to the vertical zonal system of the higher rate?

DR. HAMBRAEUS: We had the same type of filtering system for both cases.

DR. ULRICH: As the air rate increases in a turbulent room, a rate is reached where the efficiency falls off. As the ventilation rate increases, turbulence also increases and the organisms remain for a longer period of time. Twenty-five changes were optimal in the study. More particles are removed at 30 changes, but the efficiency drops off.

PARTICIPANT: We have made an observation of a system at 25 air changes an hour with ceiling diffusers in the operating room. A standing wave develops right at the centroid of the intersection of the four envelopes from the ceiling diffusers, which is immediately above the operating table. And so you get a standing wave with the velocity down where you are reducing turbulence and reducing contamination exactly at the point you don't want it. The turbulence and the induced air patterns within the room can be really very detrimental, almost independent of the air exchange rate itself.

DR. HAMBRAEUS: There is a study from a Swedish hospital that shows that with one type of ventilation the turbulence was just over the patient bed.

DR. FAVERO: If one were to compare a conventionally ventilated surgical suite with a laminar flow unit, I think we would all accept that the number of microorganisms per liter or per cubic foot of air, would be very great. In a laminar flow system one would find significantly fewer organisms, if any at all. If this is true aren't we led to the conclusion that airborne contamination is really not that important? I refer to the data that Dr. Solberg showed this morning.

DR. ULRICH: No. The data shows that ventilation rate does have an effect. I believe we have a problem of semantics of the numbers of organisms in air. The greatest number of organisms within a surgical area are generated by the people in the room. The number generated depends upon the factors that have already been discussed, essentially, the degree of activity and the number of people. There are probably other factors. Humidity also plays an important part. As the humidity goes down and the skin dries, we begin to shuck off more viable particles. These factors are difficult to control. In comparing a turbulent system to a flow-through system the half life of an organism in a room is important. The number of organisms being generated in any system depends upon the people present and in a system with 600 changes an hour, obviously the half life of that organism is going to be less than with 25 changes an hour.

The effectiveness of any particular system depends upon maintaining an acceptable level of viable particles. What that acceptable level is is a matter of concern and discussion, but if we can keep the bacterial level in the air low the rate of infection is low. One of the best sets of data from the standpoint of infection rate is being gathered at the Mayo Clinic in the orthopedic operating rooms. One of those rooms has a turbulent system with approximately 14 changes an hour. Two thousand cases of hip arthoplasties have been completed in that room with an infection rate of 1.3 percent. In another room with a rate of air exchange of about 18 per hour the infection rate was 0.7 percent. I think you are getting pretty close to the irreducible minimum.

These data indicate that the rate of air exchange does have some effect as the same surgical teams work in both rooms.

MR. MICHAELSEN: Does that also say that there is a relationship between infection rate and airborne concentration?

DR. ULRICH: Yes. I believe it does.

MR. MICHAELSEN: Any argument about that conclusion?

DR. HAMBRAEUS: Do you know the airborne contamination in the two areas? In Glasgow, Dr. White had an operating room similar to ours in Uppsala with the same number of air changes per hour and he had an airborne contamination of about 700 colony forming units per cubic meter compared to about 70 CFU in Uppsala.

DR. ULRICH: I have talked to Dr. White about that. The number that they recover from the air seems to be greater than what we found. We have speculated but no explanation appears obvious.

DR. SOLBERG: Well, I can only refer to the studies I reported earlier today where there was no correlation between air contamination and infection rates. But I wish to add that these are studies with low numbers of patients. If there was a study with about 2,000 patients in each group where the wound infection rate is measured carefully and also the air contamination over the wound during operation and correlation is found we would have to pay more attention to these results than to the results of the three earlier studies.

DR. ULRICH: I feel there are other factors that have to be considered here. I have no confidence in the quantitation of aerial bacteria in laminar flow systems because the air samplers had been designed to study turbulent systems. In turbulent systems there is a good correlation between activity and the number of airborne bacteria. In a straight through system the organisms do not diffuse rapidly enough in the period

of time they are in the room to find out what the quantitation is. Displacing the sampler by a centimeter may give an entirely different result. It's very difficult to quantitate airborne bacteria in laminar flow systems because we haven't developed a sampler that correlates with the activity of the surgical team. In the turbulent systems the correlations are good.

PARTICIPANT: I'm not sure that the point that I was trying to make awhile ago really came out. In discussing ventilation I would propose that we try to distinguish between diffusion of air within the space and ventilation of the air which would be the use of outside air. In our discussion of air changes per hour we have emphasized diffusion of air, air exchange and air dilution of the total air. The example I would like to discuss is the total air exchange needed for thermal control. We could use 100 percent nitrogen and take care of the thermal problems and look at diffusion patterns, but in a short time we could have a breathing problem. Therefore, we would have to ventilate to get some oxygen into the air to dilute the CO_2 and take care of particulate concentrations. For purposes of our discussion we need a set of semantics relative to ventilation and diffusion.

MR. MICHAELSEN: In the study that we have been reporting here, a ventilation rate is the combination of diffusion and the outdoor rates.

PARTICIPANT: Let me refer to this morning's discussion. The statement on interchange makes a difference when you bring in outside air.

MR. MICHAELSEN: We are still trying to figure out if there is a difference in infection rate. From the standpoint they are talking about it doesn't make much difference whether it was outdoor air or recirculated air.

MR. CHATIGNY: The assumption you have made is that the recirculated air isn't the same quality as outside air. We should use the word recirculated air for that which is treated and recirculated in the system and ventilated air.

MR. MICHAELSEN: Dr. Ulrich's experience would indicate that the recirculated air would be a little bit better. I have difficulty deciding that there is a relationship between airborne concentration and rates of infection or actual level of contamination. If sampling is so touchy then we really don't have any good data.

MR. CHATIGNY: Then, is the difference between 1.3 and 0.7 percent infection rates highly significant?

DR. ULRICH: It's a significant figure, but I can't remember what the value is of it.

PARTICIPANT: A good point has been raised because ultimately somebody has got to decide whether the extra energy that will reduce infection rates from 0.7 to 0.5 percent is worthwhile. It's interesting to note that at the Mayo Clinic you are talking about, they have decided to go to the laminar airflow in the orthopedic rooms because it was decided they could reduce infection rates from 0.7 down to 0.5 percent.

DR. ULRICH: When you are introducing a single change near the end of a spectrum, the amount of input becomes phenomenal for a small change. That's one of the things that you have to decide. Is it worth it?

PARTICIPANT: Then you start talking in terms of individual cases that become infected.

DR.ULRICH: The psychology of orthopedists is based on the work of Charnley in which he did reduce the infection rate from around 0.7 percent.

PARTICIPANT: The original paper in 1969 showed that Charnley got the biggest reduction when he went from open windows to a basic recirculation system. He reduced the infection rate by half and when he went to a good

inside ventilating system he cut the figure in half again. Finally, when he went to his Charnley Greenhouse, he went to 1.0 percent.

DR. ULRICH: He combined many changes in technique at once: the gowning was different, the pickup of the air from the operator was different, the airflow was different. It's only recently that investigators are beginning to separate out the important changes from the incidental things that Charnley did.

PARTICIPANT: A careful reading indicates that the biggest change came when Charnley went from the open window to the basic ventilation system because at that stage he hadn't introduced any refinements in technique yet.

DR. SOLBERG: Infection rate was reduced from 1.5 to 0.5 percent by introducing the aspiration suits.

SECTION II: PHYSICAL FACTORS

Mr. Robert Michaud
President
Michaud, Cooley, Hallberg, Erickson and Associates, Inc.
Minneapolis, Minnesota;
Mr. David Sodergren
Paul Petersson Konstruktionsbyra
Stockholm, Sweden;
Dr. Ib Andersen
Institute of Hygiene
University of Aarhus
Aarhus, Denmark
and
Professor George S. Michaelsen
School of Public Health
University of Minnesota
Minneapolis, Minnesota

The Economics of Ventilation Standards

Mr. Robert Michaud

We are looking at the aspects of ventilating systems with relation to energy conservation and bacteria control. My specialty is not what bacteria are floating through the ducts, but the implementation of rules and regulations for design of hospital buildings. There is one thing that we are learning about in today's market and society, the cost of energy, and this knowledge should stimulate further research into the heating, ventilation and air conditioning (HVAC) systems in medical facilities. I presume if we ever get a national energy policy, this is going to influence that policy.

Table 13 is a recent survey of utility charges for a large commercial corporation. The variation in a one-year period of time and the percentage increase in electrical costs are charted.

One of the better projections I have seen on energy real growth rates suggests (see Table 14.) that the percentage increase for various fuels and electricity is an addition to whatever inflationary costs are going to be. For example, in looking at Minnesota with 5.6 percent we can anticipate an 11 to 12 percent increase in the cost of energy next year.

In the mechanical and electrical design field, there are many codes, rules and regulations, and ordinances. There are many complexities involved with identifying the administrative agencies and building code publications concerned with hospital planning in Minnesota.

Table 13. Area comparisons of utility charges for a large commerical corporation.

Electrical Rates Comparison

CITY	UTILITY COMPANY	9/76 ¢/KWH	9/77 ¢/KWH	% VAR
Dallas	Dallas Power & Light	2.7	3.1	+14.8
Fort Worth	Texas Electric	2.3	2.7	+17.4
Houston	Houston Ltg. & Power	2.2	2.4	+ 9.1
Miami	Florida Power & Light	3.3	4.0	+21.2
Atlanta	Georgia Power Co.	3.1	4.2	+35.5
St. Louis	Union Electric Co.	2.7	2.7	-
Chicago	Commonwealth Edison	2 5	3.6	+33.3
New York City	Con Edison	8.4	9.1	+ 8.3
White Plains N.Y.	Con Edison	9.4	11.6	+23.4
Oakland	Pacific Gas & Electric	3.0	5.2	+73.3
San Francisco	P.G. & E	2.7	4.8	+77.8
Palo Alto	Municipal	1.4	2.6	+85.7
Santa Clara	Municipal	2.2	2.7	+22.7
Sacramento	Municipal	1.5	1.6	+ 6.7
Fresno	P.G. & E	2.9	4.8	+65.5
Stockton	P.G. & E	3.1	5.4	+74.2
Reno	Sierra Pacific Power	3.5	4.1	+17.1
Los Angeles	Dept. of Water & Power	2.7	3.7	+37.8
Pasadena	Municipal	3.5	4.3	+22.9
L.A. Suburbs	Southern Cal. Edison	3.0	3.6	+20
Las Vegas	Nevada Power Co.	2.6	3.1	+19.2
Bakersfield	P.G. & E	2.7	5.1	+88.9
Riverside	Municipal	3.2	4.0	+25
Salt Lake City	Murry City Corp.	2.4	2.5	+ 4.2
San Diego	San Diego Gas & Electric	4.1	4.3	+ 4.9
Anaheim	Municipal	3.0	3.5	+16.6
Tucson	Municipal	4.8	4.9	+ 2.1
Christown	Salt River Project	3.0	3.7	+23.3
Phoenix	Arizona Public Service	2.6	3.1	+19.2
Albuquerque	N.M. Public Service Co.	3.6	4.5	+25
Minneapolis	N.S.P.	2.9	3.22	+11.1

Table 14. Annual energy real growth rates for life-cycle costing.

Coal	5%
Fuel Oil	8%
Gas (Natural or LPG)	10%

ELECTRICITY

Region

New England-6.9%
- Connecticut
- Maine
- Massachusetts
- New Hampshire
- Rhode Island
- Vermont

Middle Atlantic-5.9%
- New Jersey
- New York
- Pennsylvania

South Atlantic-5.8%
- District of Columbia
- Florida
- Georgia
- Maryland
- North Carolina
- South Carolina
- Virginia
- West Virginia

Region

East South Central-5.6%
- Alabama
- Kentucky
- Mississippi
- Tennessee

Pacific-7.3%
- California
- Oregon
- Washington

East North Central-5.6%
- Illinois
- Indiana
- Michigan
- Ohio
- Wisconsin

West North Central-5.6%
- Iowa
- Kansas
- Minnesota
- Nebraska
- North Dakota
- South Dakota

Region

West South Central-7.5%
- Arkansas
- Louisiana
- Oklahoma
- Texas

Mountain-5.7%
- Arizona
- Colorado
- Idaho
- Montana
- Nevada
- New Mexico
- Utah
- Wyoming

For example, we are recently completing an addition to St. Mary's Hospital in Rochester. As part of getting this thing off the ground, the design team set forth to identify the codes, ordinances, rules and regulations involved. Table 15 is an example of the administrative agencies and building code publications involved with hospital planning in Minnesota:

Table 15

A. STATE OF MINNESOTA AGENCIES AND REGULATORY CODES

1. State Planning Agency
   Health Planning Division
   St. Paul, Minnesota

   Re: Certificate of Need
   According to Chapter 628, Minnesota Session Laws

2. Department of Health
   Hospital Services Division
   Licensing and Certification
   Minneapolis, Minnesota

Code: Minnesota State Board of Health Code (MHD), 1974 edition

Standards: National Fire Prevention Association (NFPA)
Life Safety 101, from 1973 and reference volumes
Medicare and Medicaid
Hill Burton (Latest minimum requirements of construction and equipment for hospital and medical facilities), DHEW

3. Department of Administration
   Building Code Division
   St. Paul, Minnesota

   City of Rochester
   Building Official

   City of Rochester
   Fire Prevention Bureau

Code: Minnesota State Building Code (SBC)

a. State Building Code regulations known and identified by the prefix SBC.

b. SBC adopting by reference:

1973 edition of the Uniform Building Code (UBC, Vol. 1;

1975 National Electrical Code (NEC);
1971 American National Standard Safety Code for Elevators, Dumbwaiters, Escalators and Moving Walks, (ANSI A17.1-1971);
1973 Minnesota Plumbing Code, (MHD 120 - MHD 135);
UBC Chapter 55 adopted as the guide for design of "Facilities for the Handicapped" in lieu of former Fire Marshal rules.

c. SBC Minnesota Heating, Ventilation, Air Conditioning and Refrigeration Code (SBC 7601 - SBC 8599)

4. "Design and Evaluation Criteria for Energy Conservation in New Buildings. Additions and Remodeled Elements of Buildings." (SBC 6001 - SBC 6013).

5. "Certain appendices which contain the listing of various National Standards referred to in the body of the Code; technical requirements for fallout shelters; and various chapters adopted by municipalities and administered and enforced by such municipalities."

"The Code is to be used in its entirety after July 1, 1972 by the municipalities in administering and enforcing the Code as well as by designers and builders. It is necessary to use the entire Code to ensure uniformity in compliance with the Code as well as uniformity in its administration and enforcement."

Availability: SBC, SFM and MHD Code from Department of Administration, Documents Section, St. Paul.

Other codes from the Department of Administration Building Code Division, St. Paul, or from the Publishers.

Uniform Building Code Volume 1
International Conference of Building Officials
Whittier, California

National Electrical Code
National Fire Protection Association
Boston, Massachusetts

American National Standard Safety Code for Elevators, Dumbwaiters, Escalators and Moving Walks
American Society of Mechanical Engineers
United Engineering Center
New York, New York

6. Department of Labor & Industry
St. Paul, Minnesota

Minnesota State Industrial Commission
Occupation Safety

Code: Minnesota Occupation Safety Code (MOSHE)

Standards: OSHA

B. FEDERAL

1. U.S. Department of Labor
Occupational Safety & Health Administration (OSHA)
Minneapolis, Minnesota

Code: OSHA

C. ACCREDITATION AND ADVISORY GROUPS

1. Joint Commission on Accreditation of Hospitals
Chicago, Illinois

Standard: Accreditation Manual for Hospitals

References: Publications of the NFPA
1973 Life Safety Code 101 referenced sections and volumes

Buildings Materials List, January 1969
Underwriters' Laboratories, Inc.,
Chicago, Illinois

Emergency Handling of Radiation Accident Cases, 1969
United States Atomic Energy Commission
Washington, D.C.

Hospital Planning for National Disaster, 1968
U.S. Government Printing Office

Principles of Disaster Planning for Hospitals, 1967
American Hospital Association
Chicago, Illinois

2. American Hospital Association
Building Codes
Standards & Safety Division of Design and Construction
Chicago, Illinois

References: Publications related to Hospital Operation and Safety

3. Department of Health, Education, and Welfare (DHEW)
Chicago, Illinois

References: 1973 NFPA 101 Safety Requirements
Medicare and/or Medicaid patients

D. STATE FIRE MARSHAL

1. 1973 NFPA 101 under the State Uniform Fire Code, effective 1975, is referenced; 1973 NFPA Life Safety 101, plus all 10 volumes, is adopted.

In energy use there are four major factors which can effect substantial savings in the energy consumption of hospitals. One major problem in trying to identify where savings can be made is a lack of metering of the various components used in the hospital. As we look at where we think the direction should tend toward, we know that the costs of energy are going to be an influential force. Indepth audits should be done not only on existing hospitals, but also on the drawing board. Unfortunately, when such audits are on the drawing board, time does not permit that kind of planning. We are faced with life cycle costing on various phases of air conditioning, mechanical, and electrical systems. This is a whole new arena and there aren't many people with experience in this area.

New disciplines are also entering into the construction of hospitals, such as construction management, and value engineers. So there are many new people working in a highly intense capital area with little experience to do the total project or jobs. Energy management programs should be a fundamental part of hospitals. Finally, possible changes in standards can effect energy savings.

At a recent presentation to the Carter-Hawley-Hale Energy Board, it was discussed that if their energy costs totally exceeded 7 percent of their gross sales they would be in trouble competitively with the rest of the market. Energy management can be viewed in two lights: first, what can I do with discipline alone that doesn't cost me money, and second what can I do item by item for so many dollars of energy savings? The Carter-Hawley-Hale group had 17 percent reduction by doing nothing other than discipline. However, for an additional reduction some money would need to be spent. It was generally found that within 17 percent it could be done with pay back of their discount cash flow procedures in five years or less.

Now, in looking at hospitals, by some of the efforts and audits of disciplinary actions only, a 10 to 17 percent reduction can be found. These are items that do not necessarily effect, as the standards now exist, the health care of the patient. Possibilities include such things as the discipline of operating the equipment and maintenance of dampers for which staff are already available to implement such an operation. Northwestern a local hospital complex, is an example (see Table 16).

Table 16. Audit of Northwestern Hospital complex.

Northwestern Hospital Complex

$ SAVINGS	INITIAL INVEST-MENT $	PAYBACK PERIOD		KWH	MMBTU	Ton-Hr.	Total Savings MMBTU/ Yr.	Savings Btu/Ft. Year
6000	10000	1.7	1. Revise Surgical supply system from 100% outside air system to conventional supply/return system with 25% minimum outside air	---	3597	25000	3972	8008
66286	60000	0.9*	2. Reduce Fan operating hrs.	1371575	22451	324070	31988	64492
3390			3. Add computerized enthalpy control in place of existing economizer cycle	---	---	169500	2542	5125
12002			4. Reduce exhaust CFM and raise mixed air temp. by 10°F during winter months. 57± to 62±	---	8001	---	8001	16131
6882	2500	0.4	5. Provide an independent air conditioning system for the computer room which would permit the reduction of operating hours of central fan system supplying computer room and other areas.	20000	3291	38280	3933	7929
				1391575	37340	556850	50436	101685

* Total Savings = $81,678
Annual Service Charges for leased line automation system = $15,000
Net Annual Savings = $66,678
Payback period = 60,000/66,678 = 0.9 Years

Building Data

N.W. Hospital	279,903 Sq. Ft.
*Harriet Walker (NurseRm)	38,357
Sister Kenny Inst.	80,600
Medical Office Bldg.	71,160
Education Bldg.	26,140
	496,160 Sq. Ft.

* Not Air Conditioned

TEI (Total Energy Index)
*1975 - 395,390 Btu/Sq. Ft.
1976 - 388,125 Btu/Sq. Ft.

* SKI opened in July 1975, but energy usage was very little until January, 1976.

No. Laundry - 1

In addition, this particular hospital is going on a computerized operational system at a cost of about $60,000 to install. The expected return is about 14 months for the $60,000. This machine will have a total energy control of all the systems where outside air is being used to ensure the best economy from the systems. Management reports will be given twice a month with running time reports on each piece of equipment.

We feel this is the direction of energy management. Although there are a number of people in this business such as Honeywell, I believe we are the only consulting office that has gone this route.

We usually give an energy budget for these people to follow and once a month provide year to date, month by month comparisons and last month to a year ago and so on. We also state the budget for the month at so many BTU's per square foot.

We have had little response from hospitals; however, merchandising groups have provided a tremendous response. First of all, in a group of say 50 to 60 stores, the manager of each individual store gets a budget on which we intentionally lower figures by 10 percent. It is to the store manager's advantage to comply with the budget because he is saving money and his bonus at the end of the year is based on net profit of the store. By getting the manager involved, employees also become involved with energy conservation. This makes a secondary purpose possible, that of educating a group of people on matters of energy conservation.

Energy budgeting is unique to every complex, for example, St. Mary's in Rochester as compared to Northwestern. We have two different operations: one being a teaching hospital and the other a pure medical hospital. Certain facilities also differ with one having a big laundry and the other with no laundry

facility. It's so important to try to achieve some means of metering the use of energy throughout the hospital complex.

In looking at the BTU's per square foot per year we got down to a 353,000 at St. Mary's which compared to Northwestern's 388,000. Why such a difference when St. Mary's even includes a laundry? We substracted the laundry and that reduced the figure to 349,000 BTU per square foot. In other words, we net 4 to 5 thousand BTU per square foot for that laundry facility. St. Mary's is a fairly well metered hospital, for example, in the metering of the steam that goes to the fuel oil heaters, or the amount of energy that goes into water treatment. They are not metered to the amount of steam that goes to a large ventilating unit and the surgical building, which is 100 percent fresh air.

For the State of Minnesota, we worked on plans for energy savings potential for Cambridge and Rochester, Minnesota mental hospitals more so than medical hospitals (see Tables17,18)

In Minnesota, we have an energy code. When it comes to hospitals, the only part of the energy code that's applicable is the envelope and that is the composite U value for the walls and the roof and so on. Any of the other standards when they conflict with those of the medical business are not to be enforced as medical standards are higher. In other words, it states in the energy code, the requirement of 5 CFM ventilation air per person but for hospitals, it's probably about five times that amount. Also, the indoor environment requirement is 78 degrees in the summer coincidental with 89 degree dry bulb and 75 degree wet bulb. It is doubtful that any hospital, much less a doctor, would ever accept such a requirement.

Table 17. Energy savings potential of Cambridge State Hospital.

Energy Savings Items	Elect. KWH/Yr.	Fuel MMBTU/Yr.	BTU/Sq.Ft./Yr. Savings	$/Yr. Savings	First Cost $	Payback
1. Discipline with Min. Cost	156,296	995	2,360	9,200	8,025	10 Mos.
2. Min. Cost (HVAC) Plumbing)	201,128	4,896	8,625	20,890	18,570	11 Mos.
3. Low Cost (Flue Stack Economizer)	---	10,992	16,980	19,788	40,000	2 Yrs.
4. Moderate Cost (Building Envelope to meet Code)	10,139	13,680	21,320	25,194	864,284	34 Yrs.
Total	367,561	30,564	49,150	75,072	930,879	12.4 Years

Cambridge State Hospital - 22 Buildings Total Area - 657,350 Sq. Ft.

Only one building air conditioned

Table 18. Energy savings potential of Rochester Hospital campus.

Energy Savings Items	Elect. KWH/Yr.	Fuel MMBTU/YR.	Savings for Btu/Sq.Ft./Yr.	$ Savings Yr.	First Cost $	Payback
1. Discipline with Min. Cost	263,292	3,610	6,025	11,463	5,860	6 Mos.
2. Min. Cost (HVAC and Plumbing) (12 Buildings)	650,168	18,325	27,455	42,336	46,505	13 Mos.
3. Low Cost (Boiler Modification)	---	14,000	18,710	21,000	30,000	18 Mos.
4. Moderate Cost Building Envelope to meet Code	28,640	12,532	16,875	19,304	800,000	41.4 Yrs
Total	942,100	48,467	69,065	94,103	882,365	9.4 Yrs

Rochester State Hospital - 12 Buildings total Area 748,290 Sq. Ft.

- 3 Buildings air conditioned

Correspondingly, the temperature in the winter shall be 70 degrees coincidental with a -14 outside temperature, but there are no rules for the hospital, and furthermore, it is stated that we cannot have any snow melting, but a hospital can. We also state that reheat systems, because of their waste of renewable resource, are not allowable in any building, but a hospital can.

We must come to grips with these conflicts in our codes. These are part of the 70 documents we are trying to work with and in many cases, they are in direct conflict with one another.

Generally, we find that with the price of energy as it stands today, or as we might expect it to be in the near future, we cannot afford to retrofit buildings to our energy code.

At Rochester, there weren't as many buildings -- three buildings air conditioned, 12 buildings total, 748,000 square feet of area. We look at the cost of the building envelope, this one happens to be 41 years, to come up to the standard of our energy code as required for new buildings. This is simply not cost effective. The application of the energy code actually is of economic value because of a reduction in refrigeration effect, heating effect and so on, and that the added cost for insulation, or double glazing, or what have you, is more than compensated by the reduction costs of those major refrigeration mechanical systems. Table 19 is a comparison of those two buildings, Cambridge and Rochester.

Let's take a look at some of the other items with regard to ventilation. We have kind of a double set of standards when ventilating patient rooms and corridors. We have the DHEW standard, which says you have got two air changes in a corridor

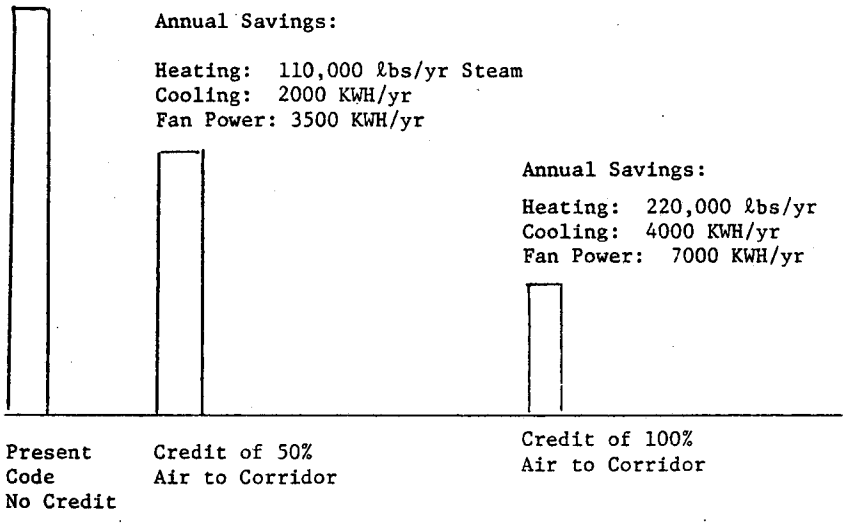
and two air changes in a patient room. The Minnesota standard isn't quite that restrictive. I can use the air that I dump into the corridor to be exhausted from adjacent toilet rooms, or whatever.

Table 19. Energy consumption summary for Cambridge State Hospital and Rochester Hospital campus.

ENERGY CONSUMPTION SUMMARY

	Rochester - Jan.-Dec. 1976		Cambridge - 1976-77 Fiscal Yr.	
	Unit	Btu/Sq. Ft./Yr.	Unit	Btu/Sq. Ft./Yr
Electrical Energy	4,929,600 KWH	22,462	3,189,480 KWH	16,826
Process Steam (Laundry & Kitchen & Domestic H.W.)	16,800 M#	22,450	22,124 M#	34,175
Space Heating	78,835 M#	132,780	62,307 M#	151,925
Total Energy Index TEI BTU/Sq. Ft./Yr.		177,692		202,916
BTU/Sq.Ft./ Heating Degree Days		18.62		20.47
Gross Area on Campus	748,290 Sq.Ft.		647,350 Sq.Ft.	
T.E.I. 1975		187,364 Btu/Sq. Ft/Yr.		207,493 Btu/Sq. Ft./Yr.
Min. T.E.I. 1978		125,000 BTU/Sq.Ft.		140,000 Btu/ Sq. Ft./Yr.

What is the purpose -- is it to make the hospital smell clean or is there a bacteriological reason? Why can't I put that air directly into the corridor? The purpose is to make up air, mainly, and let it infiltrate into the rooms through the toilet rooms that are being exhausted in those rooms and cut it in half. The code won't let me do that. There is another code in the National Fire Protection Agency that states that if I pressurized by corridors, the possibility of catastrophe from the rooms is much less. This has been confirmed in certain tests at Ohio State and other universities and also in practice. We look at the potential savings (see Figure 12).



Note: Calculations based on 100 bed hospital.

Figure 12. Effect of outside air reduction on patient's rooms by taking credit of outside air supplied to patient room corridor.

We need to go back to our codes and standards and question why some changes can't be made. The burden is with the administrator of the codes. Let's take air circulation rates, humidity standards and temperature standards in operating rooms. Our base in Minnesota is on what we call the MHD 1974. The code says you can use eight air changes, but it is an all

outside criteria. Existing hospitals have that base. In a number of places in our codes the standard in the operating room is from 50 to 60 percent relative humidity and anywhere from 70 to 75 degrees in temperature. We have just chosen arbitrarily to make some reduction. We said 75 degrees and 55 percent with 10 air changes as a base (see Figure 13). Now we are going to go to 10 air changes and we are going to dry bulb and relative humidity. We have made some energy savings. We are going to take the 10 air changes and go to 40 percent; 10 air changes, 70 degrees and 20 percent. You can see the effect of the humidity component with relation to energy use. Now I go to 5 air changes with 75 degrees and 50 percent RH and then 5 air changes with 70 degrees. This represents our current standard of design in our office of 22 to 25 changes of air an hour with this being a minimum, but again related to the national DHEW standard.

Reclaimed systems are looked at in great detail today. The basic reclaimed system that we look at is an interchange of level of air, usually with low energy intesity of 70 to 75 degrees, going across a coil and interchanging with another coil on a fresh air intake. I guess we have to question, first of all, why all exhaust air out of a hospital has to go through an interchange. There are certainly a lot of areas in a hospital that I don't believe are contaminated areas, or that air could be used directly, if it's an environmental condition of temperature and humidity that is satisfactory to use. Storage areas certainly can take air from some other source as well as the debate on the general exhaust of toilt rooms and janitors' closets.

We are now putting in sprinklers in all hospitals and generally in all of our buildings. We are finding that there isn't any great tradeoff of construction, although it is intimated in some of the building codes that you do have a trade off in your construction standards and ventilating standards. We are finding that most building officials aren't allowing these trade offs.

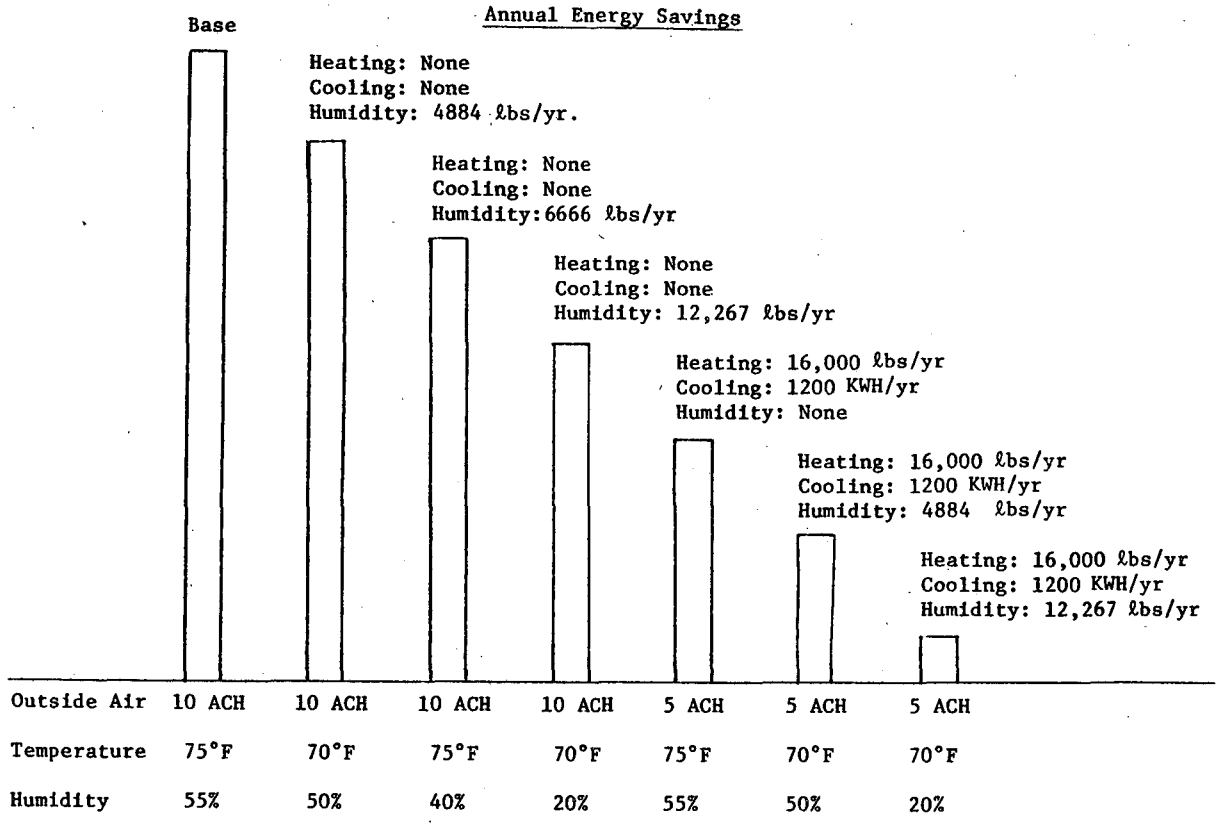


Figure 13. Effect of outside air reduction and humidity and temperature reduction in a hospital operating room.

By way of example, the National Electric Code in one of it's later editions required that all telephone cabling above the ceiling that had return air going through it should be in conduit. When you speak of fires, and again with fire people, you are really dealing with a potential fire loading of a given area. If you take a hospital or if you take a commercial office building, this component is extremely small in its potential fire loading as opposed to equipment in the room. Now, there are real restrictions on the use of those components, these chairs, the plastics in them and their effects. Sprinkler systems are now a part of our society and probably rightfully so. But, if we are putting all of these sophisticated things

in, then we should be taking out some of the unsophisticated things that aren't necessary. This is not the case because, again, going back to our Life Safety Code NFPA 101 and its 60 plus documents there is someplace somewhere in there that says you can't do it. In our Uniform Building Code they are doing it to a small degree, but our hospitals don't necessarily run with the Uniform Building Code.

Where do we go from here with relation to the environment and the mechanical and electrical systems? My firm belief is that we need to quantify where the energy is used. This is done with energy audits where absoultely every component of energy is taken into account with assistance from the building operator. At Northwestern Hospital we not only found equipment that hadn't been turned on but also found equipment that had never been turned off. We also found a vacuum in the building. Ultimately a balance was reached at Northwestern with modification and use of the present equipment. We feel that the energy audit program is a must. We are buying time with this program. We want to get the first 17 percent reduction of energy in that building without spending money. We want people to become aware of energy management and energy use.

We need to start consolidating these 70 documents and ferreting out to get something that is reasonable, felxible and with a board of appeal. In Minnesota we have a "Standard Committee of the State of Minnesota." It is a recommending committee to the Department of Administration dealing with building codes. There is an appeal process in the present building code that if you were to go through to the last step of this appeal process, the building would already be completed. Today we are promulgating the formation of a five-man appeal board that can be impaneled by an industry without cost to expedite questions. We have nothing similar to this within the hospital area.

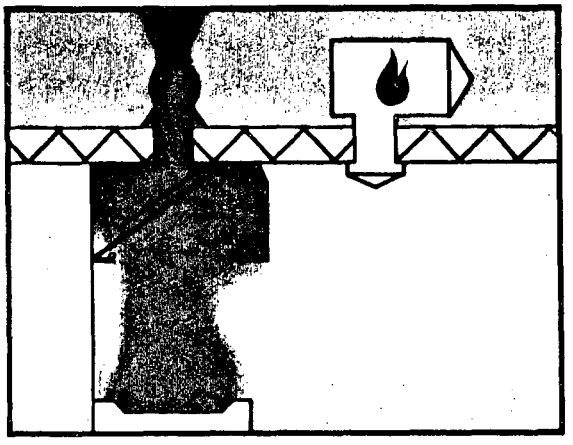
One of the major conclusions drawn has been that there is a concensus that it is not necessarily true that infections are totally airborne. This area should be looked at with respect to ventilation standards currently being used in hospitals.

Secondly, I have come away with the conclusion that some of our standards are like the standards currently being used in most of the European countries.

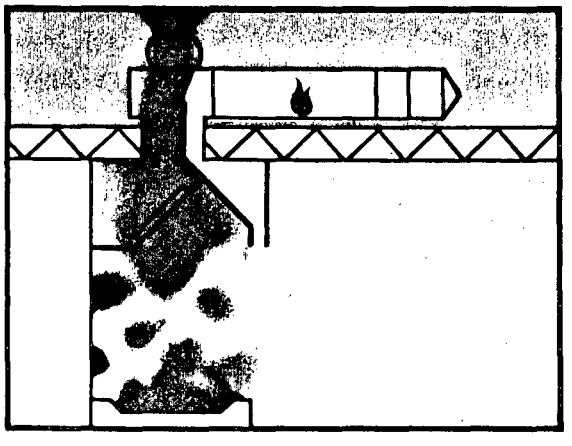
Lastly, the single most contributing factor with relation to the need for large quantities of outside air, is in the area of exhaust systems required by buildings and codes. As I have stated we have found that with the combination of the exhaust systems and/or the ventilation air requirements we need about a quarter CFM per square foot of building area per day of outside air. In looking at exhaust requirements, it seems that we have an opportunity to change standards or accept different standards for recirculation exhaust systems other than special areas such as kitchens, central sterile supply or surgical areas and related functions. We can take a kitchen in a building of 150,000 square feet or 300,000 square feet, it really doesn't make too much difference with a central food preparation area. It has an island hood and a shelf hood and generally the combination of the two take about 15,000 CFM. There are systems on the market for that particular element. Figure 14 is a push-pull system of kitchen makeup air wherein 80 percent of the exhaust volume of this 15,000 CFM comes directly from outside without conditioning. One of the problems is that this system has not been totally approved by code authorities but we have seen it in operation in some fast-food establishments.

Another combination of this is to take the dishwasher exhaust and put it into the hood as opposed to the outside air supply. Then I can effectively build this 15,000 CFM of air with about 20 percent of the quantity of the direct conditioned make-up

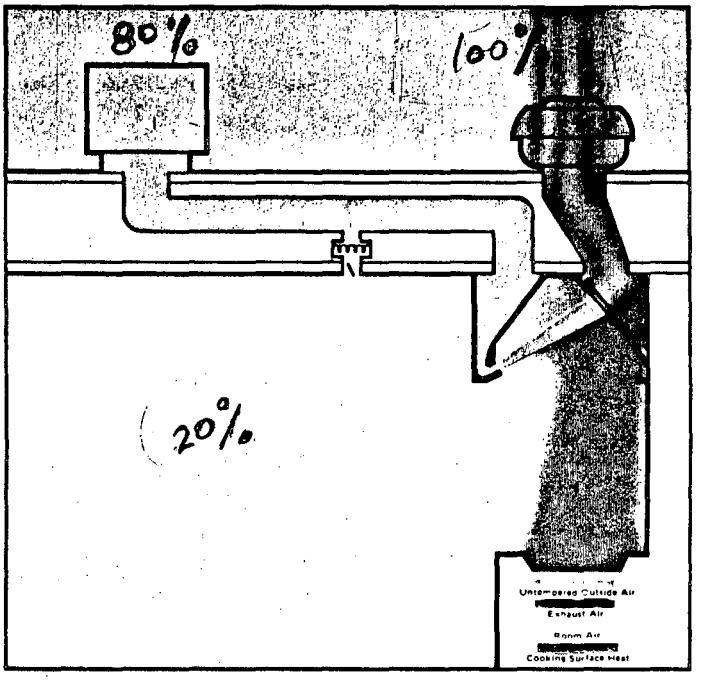
Conventional make-up air installations



Conventional kitchen exhaust installations typically consist of a make-up air unit to bring in tempered air and an exhaust hood with an exhaust fan. Smoke and fumes are usually drawn up into the hood and through a filter. The amount of air that must be exhausted is generally prescribed by state or local building codes. The exhausting of 100% tempered air requires oversized heating, ventilating, and air conditioning equipment and wastes energy. Some installations create drafts on personnel, and cool the hot foods. Other methods allow cooking fumes and vapors to escape into the kitchen. Many installations cause grease to accumulate within ducting and on the roof, creating a fire hazard. Of course, all of these conventional exhaust installations require the costly heating or cooling of make-up air.



Econovent® systems



The Econovent System is a scientifically engineered application of the venturi principle in airflow. Untempered high velocity outside air (80%) is provided through a patented air slot along the front perimeter of the exhaust hood to create a low pressure area over the cooking surface. This low pressure induces secondary air (20%) to enter under the hood, thereby retaining the cooking fumes and vapors in the capture area and pulling them into the hood exhaust system. The 20% secondary air, drawn from the building heating/air conditioning system, is directed into the kitchen through a ceiling slot diffuser. There is no need for a separate make-up air unit. The Econovent System eliminates drafts on personnel and on cooking surface because all untempered air is contained within confines of the hood area. The lower exhaust temperature provides for congealing of grease on the system's filter, thus eliminating grease laden hood, ductwork, exhaust fan and roof.

Figure 14. Systems of make-up air installations.

air. This is an area that needs study.

Also, there needs to be an allowance for the partial or total recirculation of toilet exhaust, general exhaust and so on. I don't know how fast this can be monitored or if there are microbiological problems, but I can't believe that it's insurmountable. Once this exhaust fan is cut in half, we can cut a tremendous amount of ventilation air.

We need to set a new standard for the environment within particular patient care areas. My suggestion would be that the amount of outside air should be related to the makeup required but not less than 5 CFM per active persons. This 5 CFM is a standard for other buildings in our state and for most of the buildings in the United States in the energy codes.

Physical Factors: Hospital Codes in Sweden

Mr. David Sodergren

I have understood from the earlier speeches today that the United States is in much the same position as Sweden. We are in the difficult job of balancing our needs with our resources. In a small country like Sweden, it is possible to move a little faster than you so it may be of some use to you to know where we stand regarding physical factors.

During the last few years we have developed a new building code. One part of around 70 pages is most important for heating and ventilation engineers. We have an additional code of a few pages for hospitals. Mr. Michaud mentioned that you have many rules and codes in the United States making it difficult for the designer. Our code from 1975 substitutes for the 1966 edition. The hygienic climate in the room is defined as the need of outside air in liters per person and hour. In the same code there are also rules for fire protection and regulations for energy saving. Rules for energy saving in existing buildings are now being worked out. Many of the existing buildings are going to be used for 50 or 100 years more and must be improved in order to make our efforts to save energy successful within a reasonable time. The hospital code is from 1974 and is not as energy conserving as the general building code. Although it was decided in 1975 not to change the hospital code, we know it is now time to update it.

The 1966 code stated how to construct the building. The code of 1975, however, demands a certain climatological quality. It Does not say how many panes to have in the windows, or how much insulation in the walls, but rather, it says that inside the

building there should be a thermal climate of indicated level. In that connection we are now talking about a temperature called the operative temperature which means we also include the radiation effect on the temperature. For that reason it is necessary for the designer of the building to estimate the temperature of all surfaces in the room and on that basis the operative temperature can be calculated. As you know, the human body gets approximately half of the temperature feeling from the air and the other half from the surfaces in the room. It is somewhat difficult to accept this new way to explain or indicate the indoor climate.

As a consulting engineer I see it as a commendable way to handle the question. It is better if the code prescribes the result of the work, not the construction details. A building code like our 1966 edition brakes the course of development like rocks in a stream.

The Germans also have a new code for energy conservation in new buildings.

An important question connected with the new code is the permeability of buildings. In early constructions we had some tight sheet on the inside of the wall, mostly to prevent the moisture in the air from passing into the wall and condensing somewhere when the temperature is low. That has resulted in buildings with a permeability of around 0.7 to 1.0 air exchanges per hour. Such permeability , of course, depends on the wind blowing against the walls and on the chimney effect when you have different temperatures outside and inside the building.

In writing this new code it was not known how tight it was possible to make the building nor was it known if a tighter building was desirable. Ventilation and heating engineers prefer a tight building so there will be a controlled amount of

air passing through the building independently of the wind and the temperature difference. Particularly in the wintertime it is important to have a small amount of air as possible passing through the building and also the chimney effect is stronger in the winter.

New buildings that have been tested show only 0.2 air changes per hour. When the natural ventilation is so small, it is necessary to install a mechanical ventilation system. We know that with less than 0.5 changes per hour the moisture from people will start to condense on the walls under certain conditions. We have also had problems with a too high rate of formaldehyde from building materials in tight buildings. Radon gas in stone buildings has also been a problem. More tests are needed to evaluate these problems, but at the moment we feel the most important concern is humidity.

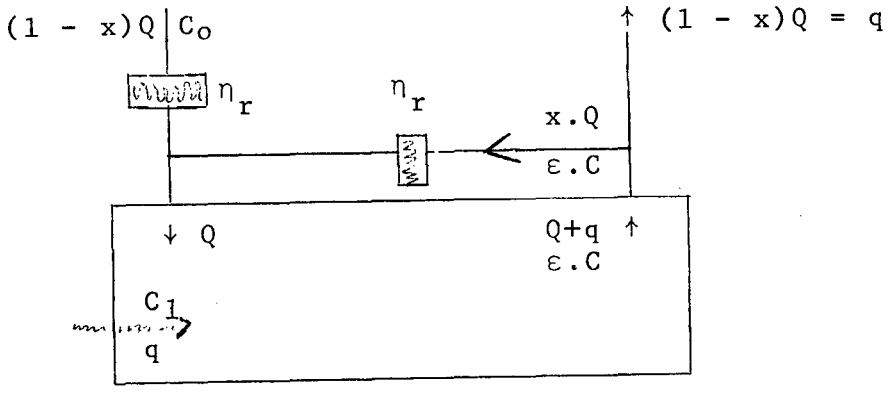
We are working together with the other Scandinavian countries to find recommendations for the tightness of new buildings and for measuring the permeability. Permeability is especially important in talking about hospitals in respect of airborne infections.

Figure 15 is the complete formula for the concentration of particles or bacteria in a room with one man giving off S particles per minute.

Figure 15. Formula for the concentration of particles or bacteria.

C = the concentration of particles in the room
C_1 = the concentration of particles in the leakage
C_o = the concentration of particles in the outside air
Q = the amount of air coming into the room from the ventilation system
q = the amount of air coming into the room by leakage
x = the percent of air which recirculates
ε = the mixing factor ($\varepsilon \leq 1$)
η_0 = the efficiency of the filter for outside air
η_r = the efficiency of the filter for recirculated air

Figure 15

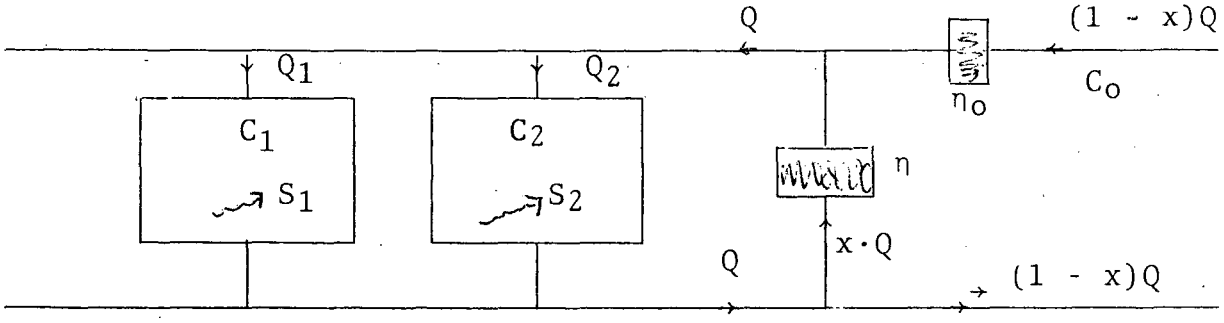


$$C = \frac{S}{\varepsilon \cdot Q \left[1 + \frac{q}{Q} - x(1 - \eta_r)\right]} + \frac{(1-x)\ (1-\eta_o)\ Q \cdot C_o + qC_1}{\varepsilon \cdot Q \left[1 + \frac{q}{Q} - x(1 - \eta_r)\right]}$$

If the formula is simplified by accepting that leakage can be neglected (q = 0) and the mixing factor ε = 1, (complete mixing) the divergence is smaller and the formula would be:

$$C = \frac{S}{Q[1 - x\ (1 - \eta_r)]} + \frac{(1 - x\ (1 - \eta_o)\ Q \cdot C_o}{Q[1 - x\ (1 - \eta_r)]}$$

With two rooms next to each other and connected to the same ventilation system (see Figure 16):



The concentration in one room would be:

$$C_1 = \frac{S_1}{Q_1} + \frac{\overline{S/Q}\ (1 - \eta_r)x}{1 - x\ (1 - \eta_r)} + \frac{(1 - x)\ (1 - \eta_o)\ C_o}{1 - x\ (1 - \eta_r)}$$

$$\overline{S/Q} = \sum_n S_i/Q_i$$

Let's say that the efficiency of the filter for outside air η_o is 95 percent and the same figure is valid for η_r. The amount of recirculated air can be 50 percent meaning:

$$\frac{(1 - \eta_r)\cdot x}{1 - x\ (1 - \eta_r)} = .0256.$$

Around 2.5 percent of the particles from the exhaust air comes back to the room. Of course it is easy to raise the amount of air Q, so much that it compensates the higher concentration $Q^1 = Q_1 \cdot 1{,}0256$. If there is a hole in the filter for the recirculated air and η_r = 90 percent instead: $\frac{(1 - \eta_r)\cdot x}{1 - x(1 - \eta_r} = .053$

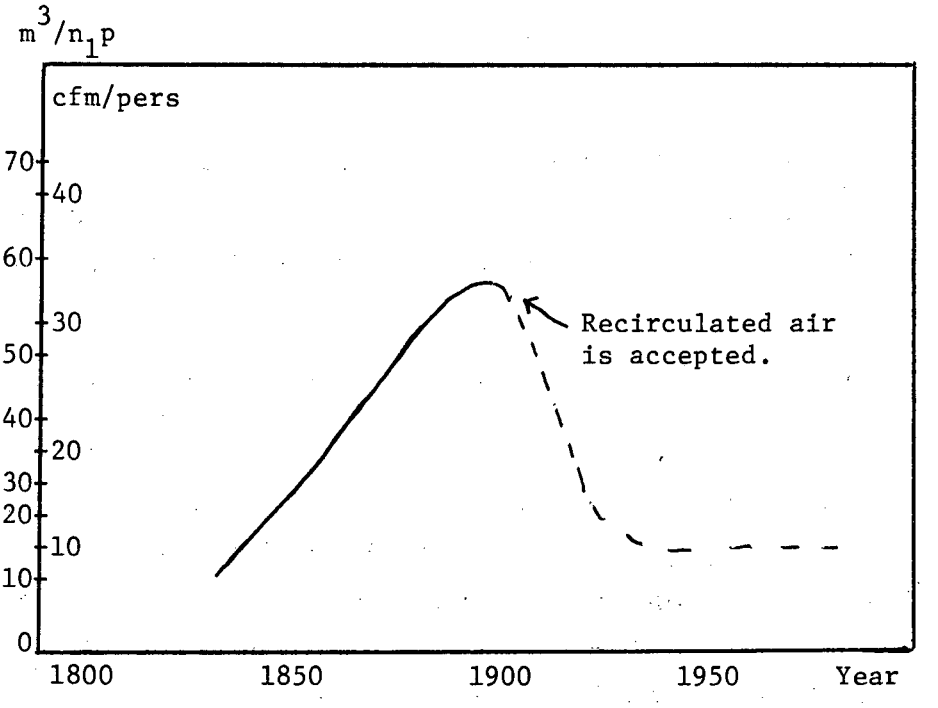
It is necessary to raise the amount of air through the room around 5 percent to get the same concentration. If it is a filter with 20 filter cassettes and the maintenance man forgets to put back one of the cassettes, we can assume that 10 percent of the air is passing through the open hole in a filter with η_r = 95% ($\eta_r = 0{,}9 \cdot 0{,}95$).

$$\frac{(1 - \eta_r) \cdot x}{1 - x\ (1 - \eta_r)} = .078$$

It is still easy to raise the Q value so it compensates the leakage in the filter. With 10 percent more air it is possible to take 50 percent recirculated air also through quite bad

filters and still get a lower particle or bacteria concentration in the room.

The amount of outside air has varied during the years and I have found an interesting curve showing the history of changing concentrations in ventilation requirements (see Figure 17). Around 1900 it was discovered that it's possible to recirculate air. I can't see why these low figures can't apply to hospitals. We are in exactly the same position in Sweden.



From Klaus A.K. et al. History of the changing conceptions in ventilation requirements. ASHRAE JOURNAL, June 1970, 51-55.

Figure 17. History of the changing conceptions in ventilation requirements.

Physical Factors: Humidity

Dr. Ib Andersen

Better procedures for heating and ventilating will result in energy savings, but in a few years more radical procedures must be introduced.

One of the more interesting procedures is the possibility in hospitals for decreasing the room temperature. The human heat balance is determined by environmental factors and personal factors. We know that the air velocity in the hotel section of the hospital is quite low and has little influence on thermal comfort. This also holds true for humidity. If you want to save energy a decrease in room temperature is the only parameter of the environmental factors which could be changed. A decrease in room temperature has to be counterbalanced either by having a bigger heat production in the subjects staying in the room, or by increasing the insulation of their clothing, their CLO value.

In Denmark this possibility has been studied by E. Hougaard Jensen at one of the technical laboratories. A sleeping in-bed patient has a total heat production of 40 watts/m^2 of which the dry heat production is 29 watts/m^2. If the patient is awake the numbers would be 47 and 33 watts/m^2 respectively. If he was awake and sitting they would be 58 and 38 watts/m^2 respectively.

The out-of-bed, sitting patient, has a total and a dry heat production of 58 and 38 watts/m^2 respectively. For the standing or walking patient the values are 75 and 47 watts/m^2 respectively. For hospital staff, the total and the dry heat production for walking and cleaning is 99 and 59 watts/m^2 respectively.

Medical doctors, who normally are less physically active than the nurses, have values of about 93 and 55 watts/m^2 respectively. If we look at a situation where the room temperature is 22 C we find that the sleeping in-bed patient needs an insulation value of 1.9 CLO units and the awake, in-bed patient needs 1.6 CLO units. CLO is a clothing insulation unit. One CLO corresponds to a clothing of about 6 millimeters of thickness. Such insulation will keep you in heat balance if you are sitting in a room with a temperature of 21 C, humidity of 50 percent and an average air movement below 10 cm/sec.

One bed cover is enough to provide an insulation of 1.9 and of 1.6 CLO. If you are sleeping with hands and shoulders below the bed cover, the insulation is about 1.9 CLO. If you are awake and have your hands and arms above the bed cover, the insulation value is about 1.6 CLO units.

The out-of-bed patient has a higher heat production and needs about 1.3 CLO units to be in heat balance; a walking patient needs about 1.0 CLO unit.

The standing-walking nurse needs an insulation value of about 0.6 CLO units which is the insulation provided by the present nurses' clothing. Use of nurses' clothing with a better insulation should make it possible to decrease the temperatures in hospitals several degrees centigrade. Bed covers with a higher insulation than used today would also be needed and the out-of-bed patient should be provided with clothing of a higher insulation value than what is presently offered. All of these procedures are very simple and no research is needed. By these means it is possible to save 10 percent of the energy used in hospitals.

Some years ago I reviewed literature about the physiological basis for the comfort factor to find out why the humidity should

be above 30 percent which is the normal statement in textbooks. The only reason for this statement was studies of ciliary movements in pieces of windpipes (trachea) kept at room temperature and humidity. Cilia are the small hairs which move the mucus in the respiratory tract. At room temperature and humidity the mucus was observed to dry out and the cleaning function stopped. From this experiment it was concluded that high indoor humidities are needed to protect the normal cleaning function of the airways. This is a strange conclusion for if you, by analogy with the described experiment, took the heart out of the same animal and placed in on a table, you would also see the heart dry out and stop beating. It is doubtful that anyone would accuse the humidity of doing this! Experiments performed on human organs removed from their natural setting do not tell the full truth -- in vitro experiments should always be followed by in vivo experiments.

The rational basis for optimum humidity dates back to a paper from 1948 by E.W. Dunklin and T.T. Puck, *Journal of Experimental Medicine*, Volume 87. Dunklin and Puck did studies on the die-away rate of pneumococci and found the highest die-away rate at 50 percent relative humidity. Airborne infection caused by pneumococci is no problem today for which reason a 50 percent relative humidity optimum based on this criterium is without meaning.

A third thing which surprised me was a textbook which stated that the cold and wet weather in England is the main cause of airway diseases in that country. In another chapter in the same book, it was stated that patients with airway diseases should sleep in cold bedrooms and humidify the air. This sounds like two contradictory statements!

Therefore, we decided to do some studies on the effects of humidity on the upper airways. We measured the mucus flow rate

on the mucous membranes in the nose because we expected that the effect of dry air on the mucous membranes should be greatest in the first part of the nose. In our study we exposed in our climate chamber young, healthy subjects to four different relative humidities. The subjects were in the chamber for eight hours at 70, 50, 30 and 10 percent relative humidity at 21 C. We never did find any effect of the low humidities and there was no speeding up of the mucus at the high humidities. There simply were no changes at all.

In a subsequent study we exposed eight subjects to 8 percent relative humidity at 21 C in the chamber for 76 hours. We found no change in the mucus flow. The mucous membranes did not dry out in the dry air.

PARTICIPANT: Are these health people?

DR. ANDERSEN: Healthy people, yes.

PARTICIPANT: Why did the mucus flow rate decrease so much at the beginning in those curves? Do you have any ideas on that?

DR. ANDERSON: No.

PARTICIPANT: Is this some kind of recovery effect taking place?

DR. ANDERSON: We always find in the beginning that mucus flow rate is unstable; it stabilizes when subjects have been in the chambers for some hours.

PARTICIPANT: What was the activity level during that time?

DR. ANDERSEN: The subjects were sitting most of the time. At the end of the experiment subjects were put on bicycles --ergometers-- to increase the ventilation of the subjects to their maximum level. Instead of a drying effect, we found an increase in the mucus flow rate. We also asked the subjects about their comfort sensations and found that no one was uncomfortable during the exposures to dry air. The studies were all performed in very clean air -- filtered through HEPA filters and charcoal filters. There was no dust or condensation nuclei, no gases or odors in the air.

Finally, we did a field study on comfort sensations at different humidities. At random, we selected 512 dwellings and visited them every month. The 512 housewives were asked about their thermal comfort sensation and their humidity comfort sensation during the last hour. We measured the temperature and humidity in that room. Whereas there was a good correlation between the thermal comfort sensation and the temperature in the room, no correlation existed between the humidity comfort sensation and the water vapor content of the air.

The conclusion of our humidity studies is that there are no physiological needs for humidification of the air. Some indirect effects on human subjects of high humidities may exist. Four favorable indirect effects of high humidities are: 1) reduced concentration of hygroscopic dust; 2) reduction of the irritation effects and the odor of cigarette smoke; 3) reduction of complaints due to static electricity, and 4) reduced survival time for some bacteria and viruses although it is unknown whether or not these are dangerous or harmless species.

Unfavorable effects of high humidities are: 1) the condensation of water vapor on cold surfaces with subsequent

growth of allergenic microfungi on wet surfaces; 2) an increase in the number of allergenic house dust mites or Dermatophagoides; 3) growth of microorganisms in humidifiers, and 4) the higher energy consumption rate for humidification of the air.

We have heard a lot about the role of skin scales as carriers of microorganisms but the human skin scales which are emissed in a quantity of about one gram per subject per day also serve as food for the house dust mite. This mite, which originally lived in birds' nests in the southern parts of Africa, has followed man and is now found everywhere on this globe, even in the socialistic countries. The mite is one-third of a millimeter in length and about the same in width.

The main reason for our interest in mites is that the so-called house dust allergy is caused by the house dust mite itself and not by the house dust. In Denmark about half of the patients with asthma are allergic to this mite, and about 2 percent of the Danish population suffers from asthma.

We have studied the ecology of the house dust mite and have found that in the indoor setting there are plenty of skin scales and many places with optimal temperatures where the mite can hide and multiply such as carpets and mattresses. The only thing of importance for the mites is humidity. We have found that humidities higher than 7 grams per kilo air, which at 21 C is about 40 percent relative humidity, causes a tremendous increase in the number of house dust mites. We have not studied hospitals but mainly homes.

High humidities will cause an increase in the emissions of formaldehyde from resins. Also at high humidities the heat loss from the body is reduced.

Physical Factors: Discussion

DR. ANDERSEN: To open discussion on this topic, I will make the following statement that in clean air the humidity is of no importance for the health and comfort of healthy subjects. Also, I assert that there is no physiological need for humidification of clean air and the indirect beneficial effects of high humidities are easily obtained by other means.

PARTICIPANT: Would anyone care to comment about the stability of viruses relative to humidity?

PARTICIPANT: Generally, microorganisms are least stable in the mid-ranges of humidity where the air source is least stable, and there is greater stability at higher and lower humidities. As far as viruses, it makes a difference if you are talking about lipophilic or hydrophilic virus. The lipophilic virus being more stable with the lower humidities and the hydrophilic being more stable with the higher humidities.

MR. CHATIGNY: I agree. Recent work has shown that there are no hard fast rules. Mainly the survival is highly dependent upon the median from which the aerosol is generated and by and large anything containing sugar tends to be protective as a generality.

DR. SOLBERG: That is a generality. I just happen to have a review paper here now with 250 references on that topic. Most hypotheses favor dehydration, concentration of toxic byproducts or an imbalance of metabolic function as the etiology of organism death. "Vaccinia virus, Venezuelan equine encephalitis virus, influenza virus, parainfluenza virus, and other myxovirus survive better in aerosols of low relative humidity, that means less than 50 percent." Those are lipophilic. "While polio virus, and herpes virus remain viable to a greater extent at relatively high

humidity, greater than 50 percent."

DR. ANDERSEN: You find that in laboratory experiments, but how important are these microorganisms in real life situations?

DR. SOLBERG: You should have put some patients with upper respiratory tract infections in rooms and examined the concentrations of viruses in the rooms. That can be done.

DR. ANDERSEN: We have done studies on rhinovirus SO_2 in England but not on humidity and rhinovirus.

MR. MICHAELSEN: You emphasize clean air. When there isn't clean air what's the situation?

DR. ANDERSEN: We have not studied that.

DR. SOLBERG: I agree with you. This is no contradiction to your data, but I think in your next study you could perhaps look at this, too, and in experiments with patients.

DR. ULRICH: There is one effect on human shedding. As humidity falls, shedding increases.

DR. ANDERSEN: Sure, but that could be controlled at source level. That's my point all the time.

DR. ULRICH: Oh, yes, that has been done by smearing people with Vasoline, but then you have temperature problems.

DR. ANDERSEN: It doesn't have to be Vasoline. It could be a normal cream or a special dress.

MR. CHATIGNY: I would like to underscore Dr. Andersen's work. The preponderance of what we're reporting and what is stated in the literature

indicates that low humidity does effect the mucus flow. It's a rare paper indeed where someone refutes that. I agree with your conclusion wholeheartedly.

PARTICIPANT: There is one other point to make in talking about patients with respiratory diseases. Dr. Ulrich has recently done a review on this in that room humidity is considered the way to alleviate problems. Respiratory therapy devices are individual and humidity can be delivered directly to a patient as needed without changing the ventilation characteristics of the entire building.

DR. SOLBERG: Not many patients need high humidity. One category is, however, children with acute laryngitis which is often caused by parainfluenza virus. The humidity is then delivered through an individual respiratory therapy device or into the patient room.

PARTICIPANT: It is my understanding that in the United States such high humidity rooms are on the way out. In respiratory therapy there is a individual device rather than a whole room device.

PARTICIPANT: Does this mean that relative humidity in surgeries can be lowered to about 20 percent? Wouldn't there be any ill effects?

PARTICIPANT: As long as explosive anesthetics aren't used...

PARTICIPANT: Mr. Michaud indicated quite conclusively the energy savings from lowering the relative humidity. The explosive anesthetic issue is being set aside as an issue.

MR. CHATIGNY: The physiological response in a healthy human was discussed and that does not consider a large open wound, for example, and its drying rate.

DR. ANDERSEN: I talked about the hotel, not about the surgical part of the hospital.

PARTICIPANT: What abut the surgical situation? How critical is it?

MR. CHATIGNY: It depends on the scope of the surgery under consideration. Obviously, a hip osteoplasty is major surgery for a prolonged period of time and an environment that provides optimum conditions is needed, whereas in a shorter operation, with much less patient exposure, I assume you could use low humidity.

DR. ULRICH: Something we were concerned with in laminar flow is that you might possibly get dehydration of tissue. However in most surgical procedures the wound is being irrigated anyway so it really doesn't relate to the humidity of the air.

PARTICIPANT: So the factor of dehydration of tissue can be eliminated. What are the other factors that require humidity in surgery?

DR. ULRICH: Shedding increases.

PARTICIPANT: Static electricity has to be considered as a problem in operating rooms. For example, in heart surgery a patient can't tolerate much stray current.

PARTICIPANT: Normally, you fibrillate the heart during heart surgery. Are you saying static electricity is going to induce fibrillation?

PARTICIPANT: It can, yes.

PARTICIPANT: If you are already fibrillating the patient it doesn't make much difference.

PARTICIPANT: It does appear to be somewhat of a problem. At the University of Minnesota they are doing an exercise in cutting down the stray current flows in and around the operating table.

PARTICIPANT: In an area where we have cardiac-care patients, we found that different levels of humidity affected transmission.

MR. MICHAELSEN: What levels of humidity are you talking about?

PARTICIPANT: We were all right between 25 and 30 percent.

MR. MICHAELSEN: Then, we have more bacteriological problems as far as humidity goes?

DR. ULRICH: All of the enteric organs, with the exception of Serratia are extremely sensitive to even 30 percent humidity. We have taken zipped open colons that have just been removed and shaken them next to our samplers but we never find gram negative bacteria. Gram negative bacteria are rarely found in air under ordinary conditions. Humidity seems to be the system of control here.

MR. CHATIGNY: I would hesitate to make a blanket statement to that effect. Again, it depends heavily on the menstruum for which the aerosol...

DR. ULRICH: It also depends on the menstruum the organism is in. The aerosol might have been pus which protects the enveloped bacteria.

MR. CHATIGNY: Right.

DR. ULRICH: What I'm talking about are organisms that are naked.

MR. CHATIGNY: Those are usually rare, except in laboratory operations where we almost deliberately create these things.

DR. FAVERO: Or humidifiers.

MR. CHATIGNY: Yes, but under normal conditions you really must consider that there are protective elements around the organs.

MR. ULRICH: That's generally true, however, the amount is also very important.

DR. SOLBERG: One effect you shouldn't forget: in a dry atmosphere, a wet skin area might feel cold and uncomfortable to the patient.

PARTICIPANT: There are a couple of points we might mention. As I understand it, explosive type anesthetics are very rarely used now in surgery. The problem of explosion is probably not as serious as it was five years ago. The question comes up regarding the hydroscopic nature of the type of gas that could be used, or the kind of cement that would be used in arthroplasty. The condensation nuclei that could form because of the moisture may be a way to deposit particles that could otherwise become airborne. I don't know that there is a whole lot of evidence but there is enough to indicate that we should have some control of humidity. At what level, I don't know. I would be concerned if we did away with humidity control in any type of an environment where we would have the possibility of a particulate or a gas generated within the space if we didn't know what the relationship would be to the water vapor.

MR. CHATIGNY: Dr. Andersen's talk has given us a lot of fruit for argument. Let's take the case where temperatures are lowered and nurses' clothing increased and another blanket is on the bed. Previously we said that shedding is perhaps one of our serious sources of bacteria and bedding is probably the most heavily contaminated part of the patient care environment in the ward. It's to our benefit to minimize the amount of bedding, not to maximize it. Again, we may be faced with a trade off situation where we really don't want to put another blanket on the bed.

DR. ANDERSEN: Dr. Lidwell found a new cloth made of unspun fibers which acts as a filter. Skin scales cannot penetrate this cloth. So if some new thinking was introduced in the making of bed covers there should be no problem with skin scales. This would also hold true if the new cloth was

used for surgical clothing to reduce the take-off of skin scales. I repeat, source control is the best method. What we have heard here today doesn't tell me that we need humidification systems in hospitals.

MR. CHATIGNY: We are now getting some fabrics with bacteria static agents. We had epidemics in the 1940s in barracks in the United States and oiling the bedding and floors was the treatment. The bacteria flow practically vanished. Again, source control.

DR. SOLBERG: And that also lowered the infection rate?

MR. CHATIGNY: Yes.

PARTICIPANT: In one of our buildings we have radiant ceilings in our patient rooms. This lowers the temperature and at the same time eliminates some of the need for extra clothing.

MR. MICHAELSEN: Maybe we could talk about dry bulb temperatures since that's an obvious source of energy savings.

MR. SODERGREN: You shouldn't only talk about energy saving in that connection, but also the comfort temperature, expecially for the person working in the hospital. Some figures were shown regarding temperatures. The suggestion was for 0.6 CLO around 70 F or 21 C. That's a little cold for the patient which is sitting. If the patients can dress so they feel comfortable in that temperature that's the way to find the best temperature for a hospital.

DR. ULRICH: Another important factor is the comfort factor in relation to humidity. Under very low humidities you feel colder.

DR. ANDERSEN: Two effects are mixed in your observation one is the condensation of water vapor in your clothing when you put on the humidifier. The condensation head makes you feel warm. If you lower the humidity from

70 to 20 percent, for instance, you immediately will feel cold due to the increase in evaporation from clothing. The second effect -- the difference in thermal comfort at different humidities in the equilibrium -- is not very pronounced. You will need a temperature increase of less than 1 C to have the same thermal comfort at 20 as at 70 percent relative humidity.

PARTICIPANT: One of the things that effects the comfort is the mean radiant temperature (MRT) of the surrounding surfaces. Your body is losing heat toward a colder surface and as you use infrared or radiant ceilings you warm the surfaces around the patient. It's quite surprising that a lower temperature can actually be comfortable.

MR. MICHAELSEN: What temperature would that be?

PARTICIPANT: It differs for each individual. At Mercy Hospital we are able to reduce the temperature...

MR. MICHAELSEN: How much lower?

PARTICIPANT: Two to three degrees. Let's say you would raise the mean radiant temperature one degree, then you could lower the dry bulb temperature approximately one degree.

PARTICIPANT: Another way to control the MRT is through the envelope. For instance, with double draping windows you can raise the MRT capacity and thus lower the dry bulb temperature. Energy savings are in two effects: 1) creation of a barrier to thermal resistance by putting up the drapery, and 2) by lowering the dry bulb temperature heat load. There are two different effects gained: 1) the response to the passive control of the MRT, and 2) comfort control at a lower temperature. The MRT is probably one of the most overlooked variables.

MR.MICHAUD: What level of humidity were you speaking of?

PARTICIPANT: A fixed level of humidity.

MR. MICHAUD: What magnitude?

PARTICIPANT: Between 30 and 70 percent within the comfort range.

MR. SODERGREN: We have used this ventilated window principle (see Figure 18) in Sweden. It gives us possibilities to keep the inside of the window warm. We are taking the air from the room through the window giving a temperature of 19 C on the inside surface when it is 20 below Celsius outside. It is about 20 C inside. Of course the radiation from the people close to the windows is much less than it should be if you have a double-paned window where you have temperatures of around 8 degrees on the inside surface.

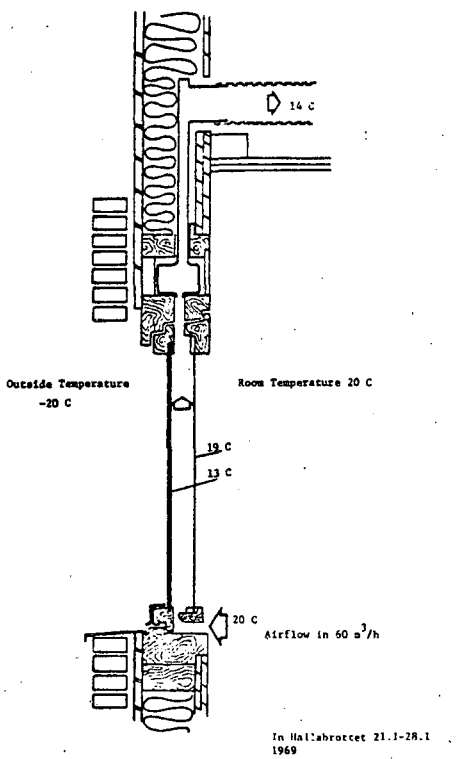


Figure 18. Ventilated window principle.

PARTICIPANT: That's double pane on the outside?

MR. SODERGREN: That's a thermal pane there but that depends on the climate in the surroundings.

PARTICIPANT: Do you have airflow between the two panels?

MR. SODERGREN: Yes. That also provides the possibilities of catching the heat from the sun in the window if you have a Venetian blind between the panes. It works like a sun collecter. With the sun on the one side, and by mixing the air from the windows with some outside air you get a comfortable temperature on the inlet air.

PARTICIPANT: If the whole body is immersed in still air and then a local area of the body is exposed to a lower temperature at a higher velocity the effect would typically be called a draft. Holten would say that he also could use a cold radiant to get the same draft effect. We don't hear much discussion about this problem, but when we begin to deal with changes in ventilation and changes in thermal control of spaces, draft can become a concern. The concept is that in still air or low velocity that an incremental change in velocity would cause a different response as compared to immersing the body in a higher velocity of air and then having a higher increment of change in velocity for the individual.

DR. DRAVNIEKS: What is the velocity of the air for the feeling of draft?

PARTICIPANT: Let's say 10 centimeters per second to start with as a low velocity.

MR. SODERGREN: P.O. Fanger in Copenhagen has made tests on all of these things and in his report where he has described the difficulties with draft (Thermal Comfort: Danish Technical Press, 1970).

MR. CHATIGNY: He reported that no directional effect was observed.

MR. SODERGREN: Yes. The velocity was just 10 centimeters per second.

PARTICIPANT: For long-term comfort, you have to consider the steady state or the average thermal balance, and also any distribution effects such as a draft or radiation would cause.

MR. MICHAELSEN: I was thinking of recovery rooms where people are coming out from under anesthesia. Is the heat mechanism of the body actually interfered with so we have to give some support, or can the body cope with the normal changes?

PARTICIPANT: This is well demonstrated in people who have spinal anesthetic in which the patient is numb from the chest down. The upper body shivers and the lower body doesn't. The patient is actually shivering to regain temperature control and does experience a coldness, but only from the numb spot up.

DR. SOLBERG: That's because the parasympatic nerve system is blocked in spinal anesthesia. This is not interfered with in general anesthesia. Spinal anesthesia is not commonly used these days.

PARTICIPANT: The temperature is also increased or decreased by basal dilatation.

PARTICIPANT: Wouldn't you also have to be careful about the thermal conditions maintained in the space for burn patients?

DR. SOLBERG: That's correct.

PARTICIPANT: I am getting the distinct impression that 50 percent relative humidity in the operating room is higher than needed and that possibly it could be cut in half without a great deal of adverse effect on the patient.

MR. CHATIGNY: Considering the cost benefit of the situation I would rephrase that and state that a defined value is unnecessary and perhaps we can tolerate a much wider range of humidity than conceived.

MR. SODERGREN: At the time of the energy crises we shut off all of the humidifiers and there was no complaint about that during those years. We have new rules now saying we shouldn't humidify the air in hospitals anymore. In operation chambers we still have possibilities to humidify the air because of the risk for explosion, but it's not necessary to keep it on all the time. It could be a good reason to talk about recirculation of air in hospitals first. If we can recirculate the air we will get a higher level of humidity because of the moisture from the people who are in the hospital. That means we will not have such a dry air as we have had before.

MR. MICHAELSEN: In general, from a design standpoint, do temperatures that you shoot for compare to the standards promoted in this country?

MR. SODERGREN: Yes.

MR. MICHAELSEN: So even in spite of high energy costs, you have not tampered with reducing temperatures?

MR. SODERGREN: No. We think there are so many other things which save energy just as well without reducing the comfort by lowering the temperature. I agree with Mr. Michaud's figures where he showed that 17 percent of the costs were quite easy to save by regulation of the air flow and the temperature in the hospital. Why should you try to reduce the temperature and get discomfort?

PARTICIPANT: If mental activity or stress causes an affect on metabolic activity, then we should compensate with thermal environmental control. Does stress cause a change in metabolic activity?

DR. ANDERSEN: Not much.

MR. MICHAELSEN: Lidwell did some studies on that years ago. He measured the sweat rate with tension during surgery. My recollection was that it was very real.

DR. ANDERSEN: It has nothing to do with the real stress because the situation studied by Lidwell and Wyon was very complex due to the heat from the surgical lamp, from the patient and so on. It's really not a study which could be used to support the hypothesis.

DR. SOLBERG: If the temperature is going to be reduced in the hospitals and of course that can save you a tremendous amount of money, then you have to put more clothes on patients and staff and you have to use more bed clothes. I don't know whether you are familiar with the bed clothes used in the Scandinavian countries. We use eiderdowns and I think that's one of the reasons why we can have lower temperatures in our hospital rooms at night. Instead of spending a lot of money on heating rooms and having only thin blankets on your beds, I think you should give eiderdowns a thought.

PARTICIPANT: I don't think we should focus only on lowering temperature in winter. We should also concentrate on being able to raise the temperature in the summer.

PARTICIPANT: We are seeing numbers that because in this part of the country 60 percent of the energy for thermal control is for heating.

PARTICIPANT: Is 40 percent for cooling?

PARTICIPANT: Not necessarily. It's around 10 to 15 percent.

PARTICIPANT: What about the southern half of the United States?

PARTICIPANT: That's a different story but the point is that in the northern parts where there is the high population of hospitals I think we are going to see more savings in the heating mode than we are on the cooling side.

DR. ULRICH: It costs you about twice as much to cool as it does to heat.

PARTICIPANT: We aren't talking so much in terms of dollars as we are in energy. If we are talking in terms of dollars, that's a different story.

MR. MICHAELSEN: A question was asked before about what are the lower temperatures in the winter with this imported blanket?

DR. SOLBERG: Many people in the Scandinavian countries like to have a bedroom temperature of 10 to 15 degrees Celsius during the night. If you put more clothes on your patients and staff, you might also reduce room temperature by 1 to 2 degrees Celsius during the day.

DR. DRAVNIEKS: There are two sides to this question. Essentially it is necessary to straighten out the commercial folklore connected to this. This can be done by such studies as Dr. Andersen's. On the other side the patient is the primary concern and if he wants a second or a third blanket you can't start arguing with him about if it is needed. The patient's comfort is just as significant a consideration.

DR. SOLBERG: Of course you have to pay attention to the individual patient's comfort. What usually happens is that patients ask the nurse to shut the heater down at least a few degrees at night.

DR. DRAVNIEKS: One of the other problems is a tremendous difference in distribution of heat. One side of the bedroom is freezing and the

other side of the bedroom is warm. These are just inefficiencies in the heating distribution systems and again, overall expense can be reduced by straightening this out.

PARTICIPANT: That gets back into the problems of infiltration of cold air around windows, which certainly is affected by the heat distribution within the patient rooms. Mr. Michaud's studies showed a payback period of 35 or 40 years in those two state hospitals that were multi-buildings. What kind of typical payback period would there be in a single structure?

MR. MICHAUD: I haven't found any under 20 years, generally around 24 years.

PARTICIPANT: So, what you are saying is regardless of the nature of the construction or single versus multi-buildings, changes in the building envelope simply aren't practicable in terms of energy savings?

MR. MICHAUD: No. The energy saving doesn't pay for it. It Maybe in terms of comfort.

DR. DRAVNIEKS: If you change to single-pane windows or triple-pane windows, there is the draft capacity of the window right there. That shouldn't be something that takes 30 years to recover.

MR. MICHAUD: Until there is a higher price for fuel the numbers are going to continue to go this way.

PARTICIPANT: Don't you escalate the price of fuel for a study like that?

MR. MICHAUD: Everybody has their own financial formulas. I use a financial formula of 8 percent escalation in energy for 25 years.

DR. ULRICH: What's the relation of volume to surface in buildings? It's pretty important in human economy.

MR. MICHAUD: I don't know if there is a real answer to that one.

PARTICIPANT: Are you going to consider the hospital as a multi-environmental structure, or is it going to be a single environmentally controlled structure? It seems you talk about many different populations within the same building and each population has requirements like operating suites and the cafeteria.

MR. MICHAELSEN: We must consider the hospitals as a multi-environmental structure as there are very sharp differences in the requirements.

MR. MICHAUD: They are considered right now in that regard, even in the building codes. What we question here is what should the environmental limits be...

PARTICIPANT: Mr. Michaud has brought up a very interesting point regarding finances and hospitals. Typically, they haven't dealt with payback unless it's a major modification to a hospital. For instance, you were showing two extremes on your payback. One problem we recently got involved in concerned double-pane windows. We came up with about a seven-year payback in this one area of the hospital, which we felt was not economically justifiable until we looked again at the deterioration of the sill and the structure. It becomes a very complex thing regarding the abilities to look at a payback justifying the type of retrofit that you're proposing.

MR. MICHAUD: There are a number of elementary computer programs -- financial programs that provide the pertinent data. Correspondingly, you could compute the escalation price of energy over a period of time of your discounted cash flow. From that you can readily answer your question on replacement of windows because of the sills or replacement of the windows because of the energy saved. The question comes down to the owners' intent of worth.

PARTICIPANT: How do you justify spending money for an energy item as opposed to some other item?

MR. MICHAUD: Because after a certain period of time you start earning money on the expenditure you made.

SECTION III: CHEMICAL CONTAMINANTS AND AESTHETIC FACTORS

Dr. Ib Andersen
Institute of Hygiene
University of Aarhus
Aarhus, Denmark;
Mr. Mark A. Chatigny
Chairman
Environmental Biology Department
Naval Supply Center
Oakland, California;
Dr. Andrew Dravnieks
Institute of Olfactory Sciences
Park Forest, Illinois;
Dr. Martin Favero
Center for Disease Control
Phoenix, Arizona
and
Mr. Robert S. Banks
School of Public Health
University of Minnesota
Minneapolis, Minnesota

Chemical Contaminants: Sources and Problems Arising Therefrom

Dr. Ib Andersen

Danes as well as other Scandinavians have always taken a profound interest in the indoor climate. In my country discussions about the indoor climate are as common as the topic of weather is in England. One reason is that we stay indoors about 23 out of 24 hours in the wintertime and another reason is that we have no natural energy resources, everything needs to be imported. Therefore, the Danish Building Code is very energy conscious. I will begin this presentation on problems associated with chemical contaminants in our environment by informing you about the essential factors of the Code.

The Code came into force January 1, 1978. In new buildings the transmission coefficient for outer heavy walls, (> 100 kg/m^2) has to be less than 0.40 per square meter and centigrade and for lighter walls (< 100 kg/m^2) 0.30. The window size is limted and has to be from 10 to 15 percent of the floor area. Installation of cooling and humidification systems are only allowed after permission from the building authorities. We find that cooling systems mainly are needed when the design of buildings is not optimal. Finally, we try to reduce the ventilation rates.

CHEMICAL CONTAMINANTS: SOURCES AND PROBLEMS

To protect against adverse climate and weather, man uses clothing, fire and shelter. Through several millennia, buildings have provided a favorable milieu for productivity and for leisure by reducing fluctuations in temperature and by

controlling wind velocity. This has been achieved at the expense of a reduced rate of air change inside the buildings. Consequently, pollutants produced by humans themselves, by human activities, and by building materials may accumulate.

The main purpose of ventilation is to dilute and remove indoor air pollutants, providing a safe, healthy and comfortable indoor environment for the occupants. To achieve this in a way that also optimizes efficiency of energy use, a scientific basis of medical and technical knowledge is needed, which, however, is not fully available today. Research on air pollution has been focused on the outdoor environment. In the last years there has also been a growing interest for the industrial work place, whereas, very little attention has been paid to the nonindustrial indoor environment. This is changing now; this Conference indicates this and also in Copenhagen from August 30 to September 1, 1978 there will be the first international Indoor Climate Symposium on "Effects of Indoor Climate on Human Comfort, Performance and Health in Residential, Commercial and Industrial Buildings."

Sources of Indoor Air Pollution

The most obvious step in conservation of energy is to reduce ventilation rates. As regards chemical contamination the need for ventilation could be reduced, and a safe and healthy air quality be maintained if the main pollution sources were identified and reduced at the source level.

Four main sources of indoor air pollution are: 1) penetration of pollutants from the outside; 2) background emission from construction materials; 3) emission from human subjects, and 4) emission from processes.

Penetration of pollutants from the outside.

Extensive measurements have been made and are being made of the many types of pollutants in outdoor air. In contrast, considering the importance of the problem from a public health point of view, very few data have been gathered on the fate of these pollutants after penetration to the indoor environment.

A bibliography on the problem from 1972 contained only 107 references and only a limited number of studies have been added since.[9] Most of the papers on this topic deal with the two main indicators of atmospheric pollutants, SO_2 and suspended particulate matter, both of which are found in lower concentrations indoors than outdoors. The reduction of the SO_2 concentration indoors is due to absorption by room surfaces and by fixtures. The reduction of suspended particulate matter presumably is due to differences in outdoor and indoor sedimentation, diffusion and coagulation processes. Ozone is also found in lower concentrations indoors than outdoors, whereas, unreactive gases like CO penetrate building structures freely, without reduction in concentration.

The natural ventilation is produced by thermal forces and by wind forces which bring about the passage of air from the outside of the building through openings, leaks and cracks, expecially around windows and doors. The air tightness of buildings has been steadily improved and today the natural ventilation rates in a new building in Denmark and also in Sweden are about 0.2 air changes per hour. Without considerable difficulty we are able to build houses with a natural ventilation rate of less than 10 air changes per hour.

Further, it is a general trend that the concentrations of the outdoor air pollutants are decreasing, especially SO_2 and suspended particulate matter.[2] The importance of this source of

indoor contaminants is decreasing, and the need for future research limited. Indoor/outdoor measurements of SO_2, mass respirable particulates, NO_2 and ozone are being measured in a six-city, 10-year U.S. study begun in 1974. This study also surveys children and adults for health effects.[6] A similar, but smaller study, is being performed at the Lawrence Berkeley Laboratory.

Background emission

Background emission in rooms is due to degassing from construction materials, fixtures, furniture, textiles, paints, and lacquers, for example.

This problem was first identified in confined spaces designed for long-term stay, such as nuclear submarines and space capsules.[10] About 15 years ago there was an extensive research program in the U.S. concerning materials for use in spacecraft as the astronauts during some of the early missions were ill and performed badly due to toxic substances from cabin materials. The problem was bigger in U.S. spacecrafts than in the Russian ones because the American spacecrafts operated at reduced pressure (1/3 atm). Therefore, an increased emanation from the construction materials was produced as the materials had been produced at surface pressure. The problem was overcome at that time by standard setting for the off-gassing properties of materials and by the introduction of environmental control systems removing the toxic contaminants. Identical measures are used in nuclear submarines, where the most serious ventilation problems are due to smoking and due to the off-gassing from certain materials.

There have been few studies about this problem in normal buildings. Goromosov, in his 10-year-old book on the physiological basis of health standards for dwellings, has a chapter about "new materials of public health importance in

housing construction."[7] He lists some studies, mainly Russian, on that topic but states that despite the widespread use of many new materials, few studies have been made of their implications for health, and there are as yet no established standards. This also holds true today. The few recent papers on background emissions deal with mercury vapors, formaldehyde and radon.

The indoor environment is the greatest source of air mercury exposure for the general population, as mercury concentrations inside places of human habitation are far greater than outside.[13] One source is latex paints, which for some years added organic mercury compounds as fungicides and mildewcides. Several studies have shown that the emissions of mercury are biggest during the first days after the application of the paint, but at the tenth day the concentration may be 1,000 times higher than that of ambient outdoor atmosphere. Sufficient mercury is present in the paint to sustain a high rate of evaporation of mercury for many years.[15]

The mercury concentrations reported are below those values recommended for workplaces ($50\mu g/m^3$) which are set for healthy, fit men eight hours a day, 40 hours a week. We have no knowledge about the physiological effects of extended exposures to the relatively low concentrations of mercury vapors in the non-industrial environment.

From building materials there is an emanation of the radioactive gas radon (^{222}Rn) with a half life of 3.8 days. The building materials, as well as the rate of ventilation, significantly influence the concentration of radon and its short-lived daughter products of solid state (^{218}Po, ^{214}Po, ^{214}Bi). In timber houses the concentration is low; in masonry houses it is higher, and the highest concentrations are found in concrete buildings, especially in basement rooms. The

concentration varies inversely with the atmospheric pressure as illustrated in Figure 19.

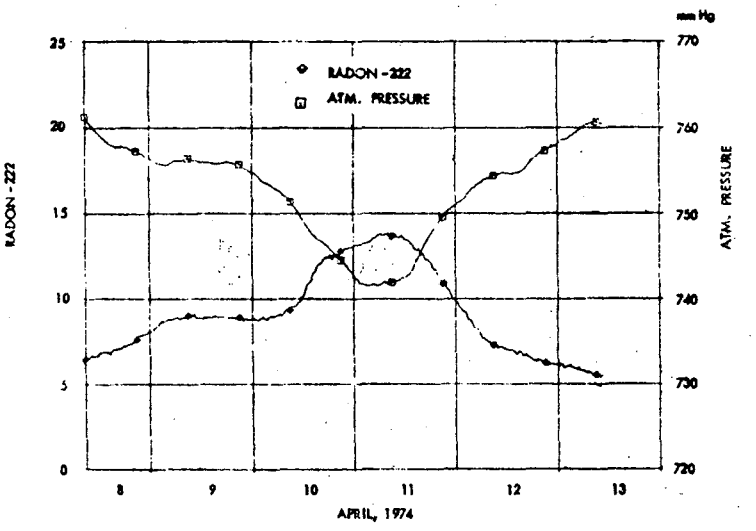


Figure 19. Radon concentration and atmospheric pressure in an unventilated basement laboratory during the passage of a pressure front. (From Jonassen and McLaughlin, 1976.)

The American limit for exposure of the population is one picocurie per liter. In Denmark the concentration in many homes is above the American limit expecially in concrete buildings; in Sweden concrete made from alunshale gives much higher concentrations of radon indoors.

This kind of pollution probably represents a health risk at the contemporary high ventilation rate. It certainly will be a health risk at lower ventilation rates or if new ventilation techniques are introduced where air only is supplied to rooms in periods where the rooms are occupied by human subjects.

Formaldehyde is another substance which may be found indoors in higher concentrations than outdoors. It is an important, very cheap, high-volume chemical, which is produced for captive use in the production of phenolic, urea, melamine and acetal resins. Formaldehyde may be given off from these materials and contaminate the indoor air. It is a very toxic substance, which causes protein coagulation, and irritates especially the eyes and the upper respiratory tract. It may also cause asthma and skin allergy.

In a survey of Danish homes we found high concentrations in new homes, or homes built during the last five years. The average indoor formaldehyde concentration was 0.62 mg/m^3. The Danish and the German threshold limit value for workplaces is 1.2 mg/m^3 and the corresponding American value is 3 mg/m^3.

The source of the formaldehyde was chipboard (particle board) which is made of woodshavings held together by a glue, usually a ureaformaldehyde glue. The results of the study in the homes and a climate chamber study was that the off-gassing of formaldehyde was directly proportional with temperature. A temperature increase of 7C doubled the emanation of the formaldehyde. The emanation was also directly proportional to the water vapor concentration of the air and an increase in humidity from 30 to 70 percent at 22C also doubled the formaldehyde concentration in the air. The formaldehyde concentration was directly proportional with the amount of material used per unit room volume. There was a hyperbolic decrease in formaldehyde concentration at increasing ventilation rates.

From the data a mathematical model for the room air concentration of formaldehyde (see Figure 20) was developed which is now used for prediction purposes.[1]

Mathematical model for the room air concentration of formaldehyde. (From Andersen, Lundquist and Mølhave, 1975)

$$E = \frac{(RT + S)\ (dH + b)}{1 + (n\ c/d)}$$

E: room air concentration of formaldehyde

T: air temperature °C

H: water vapor concentration g/kg dry air

N: ventilation rate per hour

d: board area per room volume m^2/m^3

a, b, c, S and R are constants

Figure 20. Mathematical model for the room air concentration of formaldehyde.

In Denmark we have many complaints about the quality of air in new buildings, especially in the fist years of occupancy. The complaints are mainly irritation of the eyes and upper airways, dryness of the nose, a feeling of dryness in the throat and headache. Formaldehyde was the cause in many of the cases which we have been investigating, but there still are many cases where formaldehyde is present in such a low concentration that it cannot be the cause of the problem. We have found in those cases a wide variety of hydrocarbons in the indoor environment in concentrations up to 1.6 mg/m^3. The U.S. National Air Quality Standard for hydrocarbon in outdoor air is 0.16 mg/m^3.

In a study in offices where there were many complaints about the indoor climate, we found concentrations of about 1.03 mg/m^3 of hydrocarbons. A total of 26 different compounds were found in the air (see Figure 21). Most had an irritating effect on the airways.

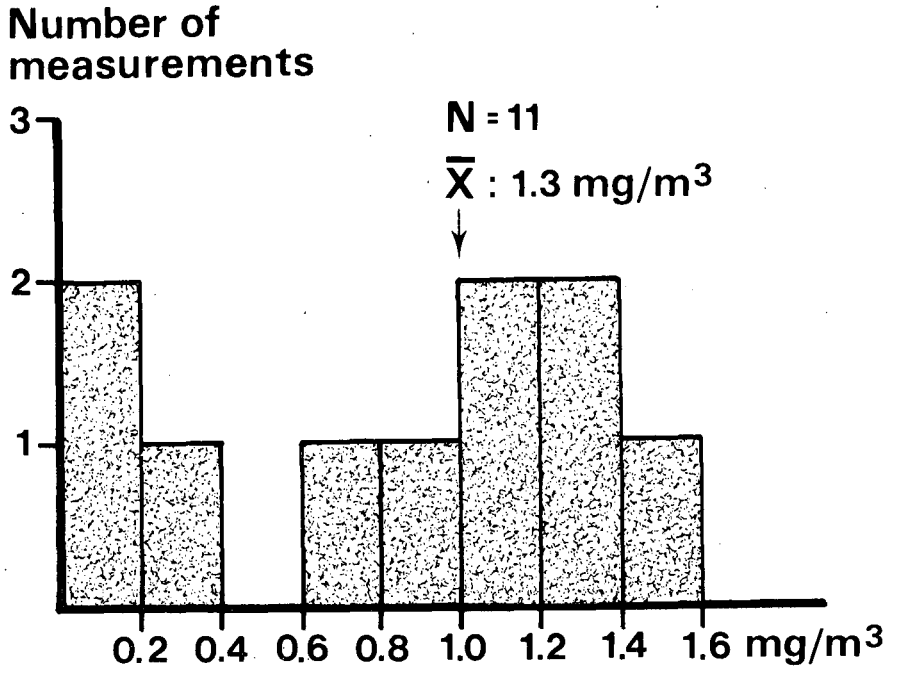


Figure 21. Concentration of hydrocardons in indoor air in 11 offices with non-thermal complaints on the indoor climate.

We have not proven that the hydrocarbons caused the complaints mentioned, but the hydrocarbons are the only compounds found in relatively high concentrations in the rooms where the occupants complain. One main source of hydrocarbons is emanations from construction materials. We have recently studied 20 building materials with gas chromatographic-mass spectrometric equipment and found an average emanation of 23 chemical substances per construction material. The concentration measured at a steady state in an air tight enclosure were from 0.12 to 1,170 mg/m^3 kg. The materials fell into two different groups: 1) glues and sealing materials,

including those used for sealing ventilation ducts with a gas-off steady state concentration of more than 200 mg/m^3 kg, and 2) the remaining substances had a gas-off steady state concentration of about 2 mg/m^3 kg.

We consider a reduction of the background emissions in combination with an improved air tightness in buildings as essential steps in energy conservation procedures in any kind of building. This reduction will also allow for very low ventilation rates, for example, down to 0.1 h^{-1} air changes per hour, or complete shut down of the ventilation in rooms without human occupancy and without any activity. This can be achieved on condition that: 1) off-gassing properties of construction materials are tested (chemical composition of gas-off, rate of gas-off);2) mathematical models for the gas-off at different temperatures, humidities, ventilation rates, are developed, and 3) standards for permissible concentrations of pollutants for continuous exposure are available.

Knowledge about these data for construction materials would make it possible in the stage of building design to calculate the concentration of toxic and odorous substances in the indoor environment. If one or several of the standards for permissible concentration were surpassed in the prediction models, the amount of the relevant construction materials could be reduced to a safe level or the material could be replaced by another material. A procedure of this kind would be in accordance with the spirit of the U.S. Toxic Substances Control Act. There is sufficient knowledge of formaldehyde to do this. Denmark and Sweden already have preliminary standards for emission of formaldehyde from chipboard and Germany and the Netherlands are soon to follow. For other materials our knowledge is insufficient and a setting of emission standards for the most common construction materials is still some years ahead.

Today there are no technical difficulties in analyzing the emanations from construction materials or in the making of mathematical models. The greatest problem is the prediction of the biological effects of the pollutants because at present we only have a few air quality standards for continuous exposure of human subjects. For workrooms Governmental Industrial Hygienists in the United States have recommended time weighted averages (TWA) for about 700 substances, whereas, the U.S. National Ambient Air quality Standard for 1971 only contains six substances: SO_2, particulate matter, CO, NO_2, photochemical oxidants, and hydrocarbons. A standard for lead will soon be added.

Air quality standards for indoor air should be set according to the same principles as those for outdoor air. There is no rational basis for using one-tenth of the TWA values as suggested in ASHRAE Standard 62-73. To close the gap between the six national air quality standards and the 700 TWA substances or the 25,000 substances in the toxic substances list, the Environmental Protection Agency (EPA) has tried to estimate the permissible concentrations of pollutants for continuous exposure by two different approaches.[8] (See Figure 22)

The first approach is based on the correlation between the TLV standards and the LD_{50} values of 191 compounds ($r = 0.70$). Using the lower 95 percent confidence limit of this regression line a low estimate for TLV for all substances with a LD_{50} was made. By multiplying by 40/168 (the fraction of time one is exposed to a working place environment) and then multiplying by 0.5 due to the relative susceptibility of young children a formula for the maximum permissible air concentration of a compound related to its LD_{50} value was found: $X_p = 4.77 \times 10^{-5}(LD_{50})$.

The second approach of the EPA is based on biological consideration. Data on biological half-lives give criteria values

differing by only approximately 10 percent from those calculated by the first approach formula. It is abundantly clear that calculations like these are based on many assumptions, and that this kind of approach has limitation. At present, however, it is the only way to get preliminary values for air quality standards for continuous exposure for the great number of chemical substances met in the indoor environment.

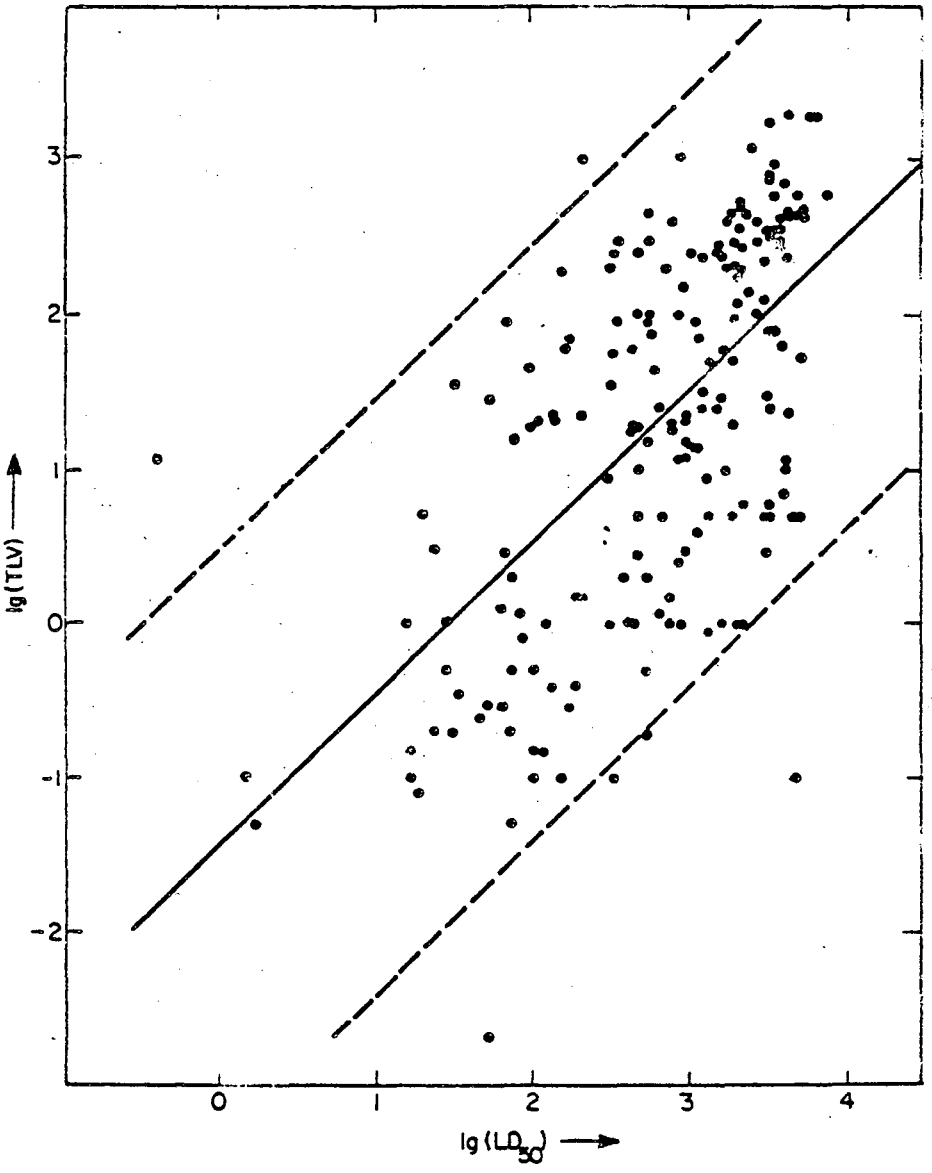


Figure 22. Plot of log TLV versus log LD_{50} for 191 non-agricultural compounds. The linear correlation coefficient is 0.7. (From Hardy and Schindler, 1976.)

Emission from human subjects.

Emission from human subjects consists of heat, water vapor, particles, CO_2, CO, acetone, ethanol, methanol and odorous substances.[5] These chemical substances all have a very low toxicity. To comply with the basic physiological needs of the human organism only a low supply of air is necessary. For CO_2 we know that submarine personnel may be exposed to 3 percent for several months without health effects and with only slight discomfort. The concentration of 3 percent corresponds with a ventilation rate of 0.6 m^3 per person per hour. To comply with the TWA value for workrooms of 0.5 percent only 4 m^3 per person per hour is necessary.

The basis for the existing ventilation requirements for elimination of chemical substances emissed by human subjects is the studies of odor levels performed by Yaglou in the 1930s.[16] Yaglou's experiments were so well planned and performed that they have never been repeated or confirmed. The difference between the 4 m^3 of air per person per hour required for dilution of CO_2 and the Yaglou criteria of about 30 m^3 per person per hour, however, is very large. It appears that high priority should be given to research where the response of human subjects to human emissions is studied.

Emission from processes.

The emission from processes is the fourth main source. In non-industrial indoor settings, where no cooking, washing or drying procedures are performed, the human activity which causes the greatest pollution is tobacco smoking.

Passive smoking. Data in the literature indicate that an average smoker's consumption of cigarettes is 1.2 to 1.4 per hour, but individual smokers vary greatly.[3] With data on smoke

generation, size of occupied space and ventilation rates, it is possible to calculate the concentrations of the different tobacco smoke components (formaldehyde, acrolein and particulate matter). The risk for development of chronic pulmonary effects due to this exposure is considered non-existing at the ventilation rates of today, but in rooms with very low ventilation rates the risk may be substantial.

Little information is available on threshold levels for the acute effects of environmental tobacco smoke, irritation of the eyes and the upper respiratory tract. The ventilation required to avoid eye irritation in the non-smokers is about 12 m^3 per hour per cigarette; for nose irritation about 30 m^3 per hour per cigarette, and for annoying smell about 50 m^3 per hour per cigarette in dry and warm air (25C, 33% RH). Extensive studies of these phenomena have not been performed and no dose response relationships have been established

The ventilation requirements per cigarette are of a magnitude that makes it imperative in an energy conservation period to ban smoking in most rooms. Smoking should be in rooms designed for that purpose with a special exhaust system or air cleaning equipment for recirculation in the room.

Smokers also pollute when they do not smoke. During the non-smoking periods a substantial amount of CO is exhaled. We did a study on passive smoking where we measured CO in our environmental chamber, but background values varied a great deal from subject to subject. We found that during a non-smoking period there was a substantial amount of CO exhaled from the smokers. Smokers have a CO-hemoglobin level of 10 to 15 percent of the total hemoglobin.

In the hospital setting many different gases and vapors are found. I consider the review in the conference materials very

good, and I shall avoid a repetition of it here. This also applies to the health hazards in the form of increased incidence of abnormal pregnancies in female anesthesiologists exposed to anesthetic gases.

A group of hospital personnel, which we are presently investigating in the Scandinavian countries is the female technicians in the pathology, histology and cytology laboratories. Large quantities of organic solvents, expecially toluene and xylene are used in these rooms. The preliminary result of our investigation is that a number of abnormal pregnancies--spontaneous abortion, congenital malfunctions and stillborn babies--is much higher among the female technicians than in the normal population.

Other processes. Housekeeping functions such as cleaning floors and polishing furniture also give rise to a chemical indoor air pollution because such things as shampoos and soaps contain organic solvents, bactericidal substances and odorants. The amount of chemical substances added to the atmosphere from these sources is not known, but it may be calculated from the consumption and from the recipe of the products. A study of this kind would make it possible to calculate the need for ventilation to take away the pollutants generated by these processes. Subsequently, it should be possible to develop products and cleaning methods which minimize the need for ventilation.

Another reason to consider the use of products for cleaning and disinfection in hospitals is that these products are toxic and give rise to severe occupational health problems. Nurses and personnel performing cleaning functions have the greatest number of toxic and allergic skin diseases of any occupational group. Most hospitals are using far too many products for the normal cleaning functions. In a recent study at a 1,500-bed

hospital we listed 35 products for cleaning functions and no one really knew what chemical substances were in the products.

Therefore, the number of different products should be reduced, and secondly, there should be a shift to products acceptable from an occupational as well as an environmental health point of view.

Summary

The chemical pollution in the indoor environment is very complex. Pollutants stem from four main sources: 1) penetration of pollutants from the outside; 2) background emission from construction materials; 3) emission from human subjects, and 4) emission from processes. Very little is known about the source, emission rate and concentration of the various atmospheric contaminants. Also, the knowledge about the effect on man of these long-term, low-level exposures of individual pollutants and combinations of pollutants is scarce. The best strategy in any fight against pollution is control at source level, for which reason background emission and emission from processes should be minimized. In rooms without a constant human occupancy this approach will make it possible to have very low ventilation rates during periods without human occupancy. The emissions from human subjects cannot be controlled at the source level, but the need for ventilation for the control of this emission may be quite different from today's standard, which is based mainly on a non-repeated study from 43 years ago.

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Odors, Air Fresheners, Air Ionization and Stale and Fresh Air

Mr. Mark A. Chatigny

Aesthetic systems include almost all of the external stimuli to occupants. We will focus on those stimuli which have to do primarily with heating and ventilating and air conditioning systems. Most of these factors interact to varying degrees. For example, temperature and relative humidity certainly interact. Odors obviously interact within themselves, and also with the environment and temperature. Dr. Dravnieks will speak at length about that factor.

Let's set the stage for the psychophysiological effects with respect to air conditioning. Aesthetics can be expressed as comfort conditions and described by such terms as pleasant, invigorating, drafty, chilly, stuffy, hot, uncomfortable, or smelly. You pick the adjective and it's being used.

Basically, the psychophysiological conditions we probably seek are to have the indoor environment the least disruptive to our work or rest, and secondly, on a positive note, considering the environment in hospitals, the environment should contribute to the well-being and recovery of the patient, or at least it should not inhibit his recovery.

Dr. Croome provided a physical model to which we physicists and biologists can relate (see Figure 23). This is Croome's second model in which he has a circle he calls a permeable membrane. This is probably familiar to a microbiologist. This permeable membrane is dented or penetrated by peripheral stimuli.

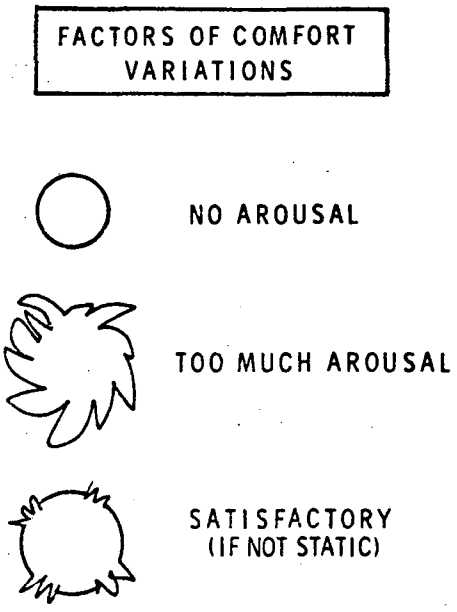


Figure 23. Factors of comfor variations.

Let's look at some of the factors that go into these areas. We have our train of thought; our autonomic systems, and the system which keeps us in balance and keeps our temperature reasonably uniform. The thought process is not autonomic obviously it is affected by the peripheral stimuli. Some of these peripheral stimuli that you would expect to find in heating and ventilating systems are listed in Figure 24

The model in Figure 25 relates more to concrete terms. On the vertical axis there is a sense of arousal or the excitement or effect of the peripheral stimulus on us. Our output capacity is on the horizontal axis. In an over arousal situation our capacity to perform work is minimized as illustrated by the light gray section in the middle. Our surroundings can even cause us to be over excited. For example, a sharp noise will arouse you and at the same time distract you. Optimally, we would like the condition where we can perform work, rest

and recover without really paying any attention to our surroundings or having it intrude on our train of thought.

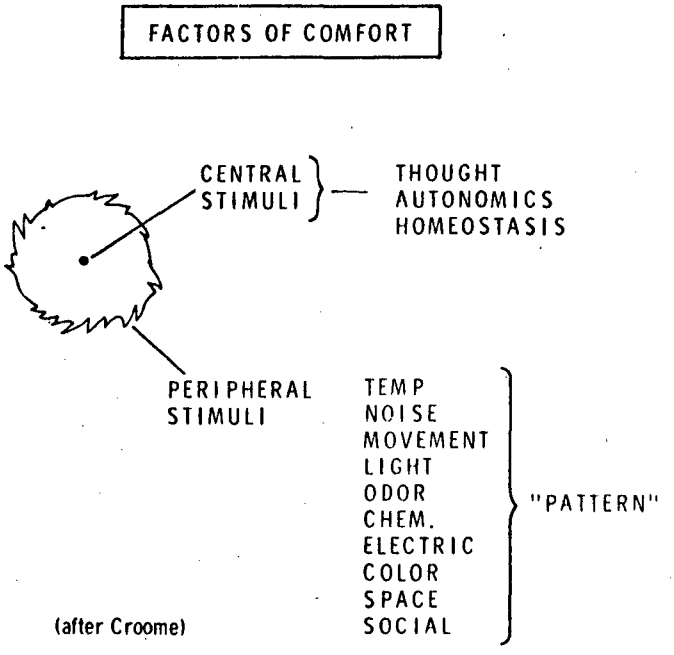


Figure 24. Peripheral stimuli in heating and ventilating systems or comfort factors.

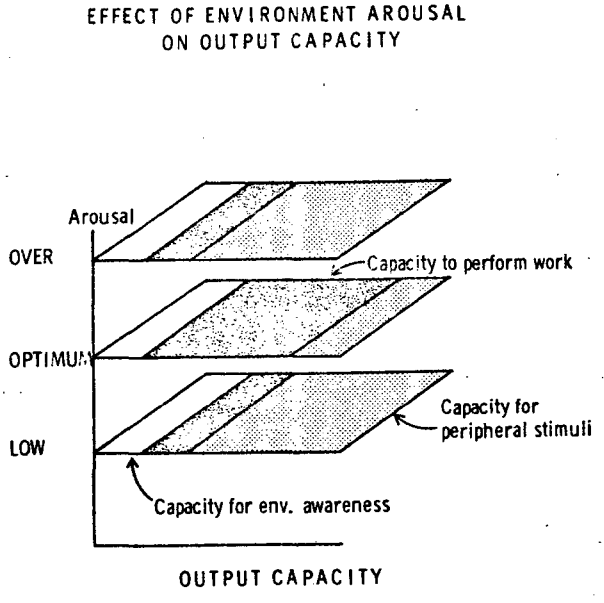


Figure 25. Effect of environmental arousal on output capacity.

On the lower level of the bottom plane we have a tremendous capacity for peripheral stimulation, but it does not occur. It might be compared to sleeping. While we have the capacity, we aren't using that capacity for stimulation.

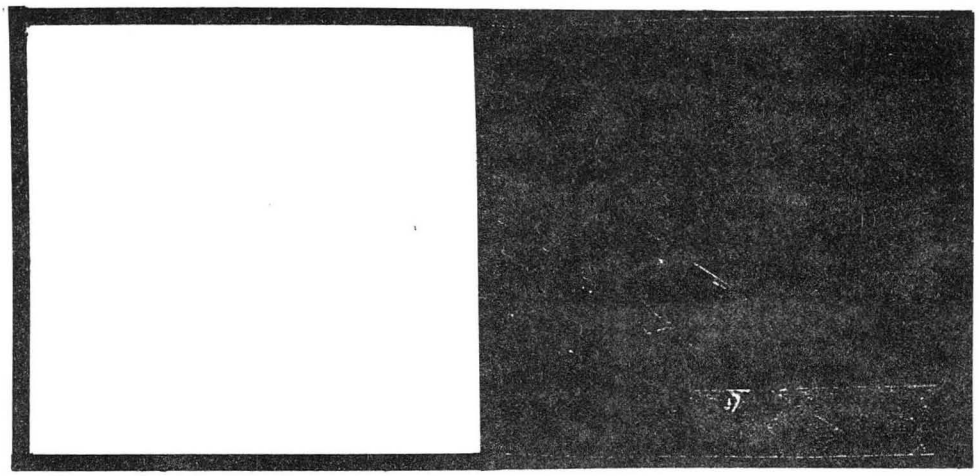


Figure 26. Example of no stimulation.

Figure 27. Example of no stimulation.

It is a no color situation. A color can be used as the model for stimulation. If you all stare at that blank wall for awhile you will find that it is not very stimulating or exciting. Now, if I switch to the other end of the spectrum as in Figure 27 that too is not very appealing.

What are the comfort conditions that meet these requirements in HVAC systems? Seven requirements are listed in Table 20.

Table 20. Seven general HVAC comfort requirements.

1. COOL AS COMPATIBLE WITH COMFORT
2. ADEQUATE AIR MOVEMENTS - NO DRAFTS
3. VARIABLE AIR MOVEMENT
4. RH $\ll$ 70%
5. TEMP. OF SURFACES $\gg$ AIR
6. TEMP. AT HEAD $>$ TEMP. AT FEET
7. "FREE" OF ODORS

Temperature, the first factor we considered, is obviously affected by the humidity. Figure 28 taken from Koch and Nevin, shows that the effect of relative humidity is not exact. It's quite a broad spectrum going from slightly cool to slightly warm.

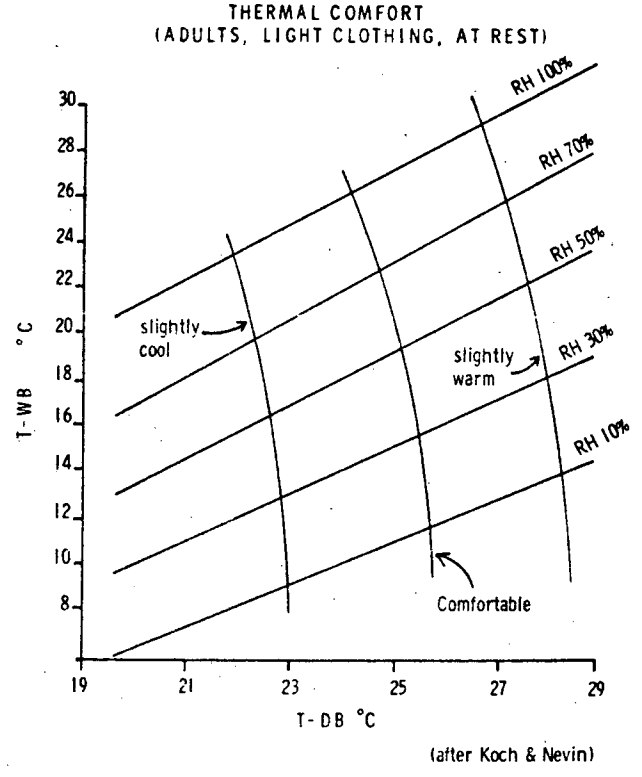
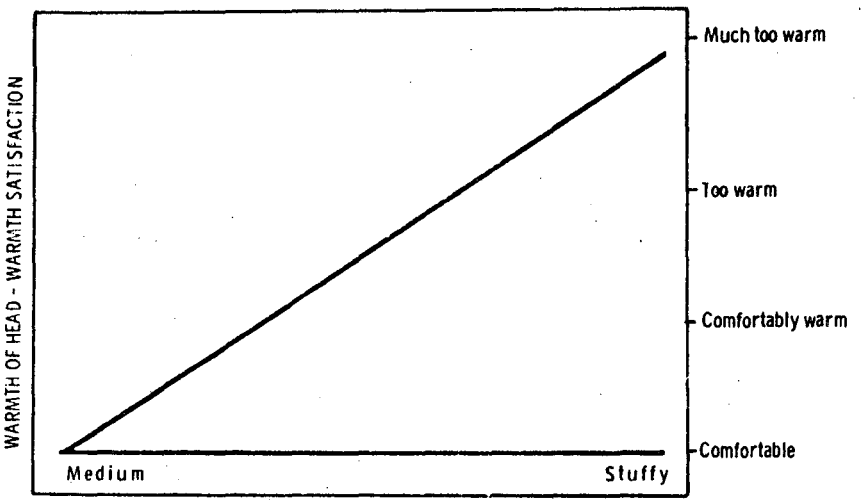


Figure 28. Thermal comfort.

Now, we get into the question of should the temperature in one part of the room be different than the other, s hould we have a gradient? Bedford, as illustrated in Figure 29 has shown that the forehead and feet are quite differently responsive to temperature conditions.

With the same factor of temperature we begin to see where it's like "stuffy" coming up (see Figure 30) and then we find the temperature up at our head level in the vertical axis compared to the medium to stuffy conditions. On the horizontal

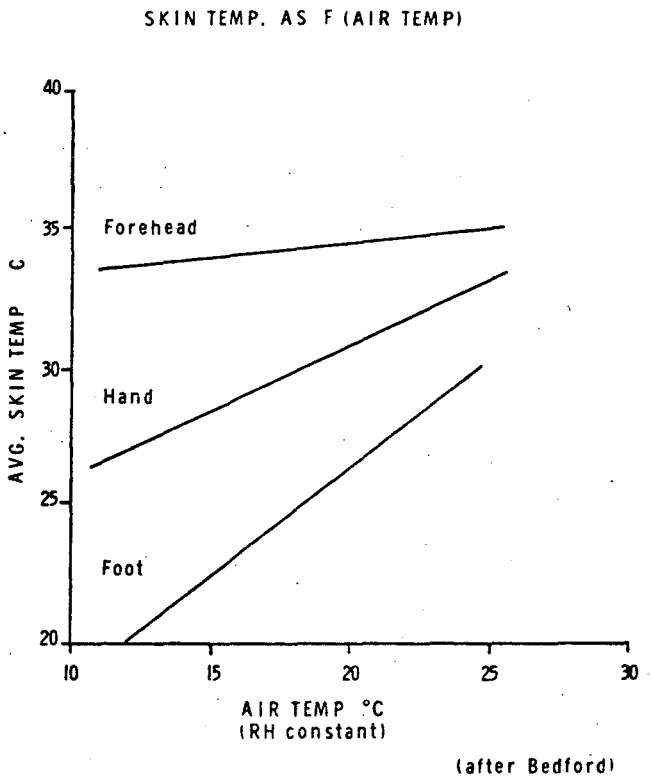
axis you see that a warm head tends to produce answers like "it's stuffy in here."



WARMTH AT HEAD LEVEL AND STUFFINESS

(Croome and Roberts)

Figure 29. Temperature and the question of gradiency.



(after Bedford)

Figure 30. Temperature and stuffiness.

Table 21 is taken from the ASHRAE guide and from Dr. Yaglou's work in 1936. It is a good definitive piece of work and I show it because it does set the stage for what Dr. Dravnieks is going to say and it is, in my mind, the most important factor aesthetically in the HVAC system. In the final analysis, it is the lower limiting factor of ventilation in many cases and it needs critical examination.

Table 21. Minimum odor-free air requirements to remove objectionable body odors under laboratory conditions.

Table 1 .... Minimum Odor-free Air Requirements to Remove Objectionable Body Odors Under Laboratory Conditions[1]

Type of Occupants	Air Space per Person Cu Ft	Odor-free Air Supply CFM per Person
Heating season with or without recirculation. Air not conditioned.		
Sedentary adults of average socio-economic status	100	25
	200	16
	300	12
	500	7
Laborers	200	23
Grade school children of average socio-economic status	100	29
	200	21
	300	17
	500	11
Grade school children of lower socio-economic status	200	38
Children attending private grade schools	100	22
Heating season. Air humidified by means of centrifugal humidifier. Water atomization rate 8 to 10 gph. Total air circulation 30 cfm per person.		
Sedentary adults	200	12
Summer season. Air cooled and dehumidified by means of a spray dehumidifier. Spray water changed daily. Total air circulation 30 cfm per person.		
Sedentary adults	200	<4

Rae and Smith in Table 22 calculated some background odor levels. They had acute odor conditions and background odor conditions. Background odors did not persist over prolonged periods of time and were usually sporadic and at low levels such as bed bath for patients or treating wounds within a room. It's fairly obvious that the air changes per hour and percent recirculation, had little or no effect on the response to these areas. Persons in hospitals also seem to become accustomed to acute odors. Rae and Smith had to conclude that under no conditions of temperature and humidity did they find any special case where odors were overwhelmingly objectionable except in a very few cases where they had a lot of separating rooms and things of this nature.

Table 22. Summary of background odor results in a hospital ward. Rae and Smith.

Mechanical air changes per hour	% Re-circulation	No of interviews	No of complaints	% of complaints
6	0	179	12	6.7
6	80	170	8	4.7
4.5	0	61	4	6.6
4.5	80	88	4	4.5
3	0	83	4	4.8
3	80	78	7	9.0
	Totals	659	39	5.9

Table 3. Summary of background odor results in a hospital ward. Rae and Smith (17).

There are certain parameters associated with air freshness (see Table 23). Such factors seem to form a pattern. A CO2 level of less than one percent and an oxygen level of about 20 percent are pleasing. People like a low level of large particles. Large means cigarette smoke or dust. Particles high in smell tend to be high in molecular size. Odors that people seem to like are the mild odors: sweet as a rose, fresh as the ocean, beautiful pine scent. Temperature should be slightly cool or as cool as can be comfortable: 1.5 to 2.5 C below an ambient condition or standard condition. Air ions are a more controversial subject and we find that the preponderants of work says that negative ions make air freshness.

More recently we have had the moderate concensus that it is desirable to approach the natural condition wherein there is an even balance of positive and negative ions. The balance of positive and negative is slightly to the positive side, but they prefer it to the slightly negative side.

Table 23. Parameters associated with air freshness.

PARAMETERS ASSOCIATED WITH AIR FRESHNESS	
CO_2 LEVEL	< 1%
O_2 LEVEL	20% +
PARTICULATES	LOW/LARGE - HIGH/SMALL
ODOR	MILD (OCEAN, PINE)
TEMP.	ca. 1.5 - 2.5 C BELOW STD.
AIR IONS	EVEN ⟶ -----(SMALL)
AIR MOVEMENT	MODERATE
OZONE	NEGLIGIBLE
SPACE CHARGE	-

Air movement should be moderate, and none of us like the smell of ozone. Space charge is a factor largely because it seems to effect the air ions concentration and we look for negative space charge so we can have a negative balance of those ions.

Let's talk about stuffiness (see Table 24). With a CO_2 level of 2 percent or greater we have stuffiness. At the start of the nuclear submarine program we were running about 1.8 to 2 percent CO_2 in the submarines for 40 to 60 day patrols. Indeed, we did have headaches and stuffy feelings. Now it's running between 1 and 1.5 percent in nuclear submarines and we have no complaints and the environment is quite satisfactory to the people. An excess of positive ions has been stated to be associated with air staleness or stuffiness. That's a little hard to separate again because the excess ions might come from smoking characteristics. Smoke is bad enough and the addition of a few ions doesn't seem to make that much difference.

Table 24. Parameters associated with air staleness or stuffiness.

CO_2 LEVEL	>2%
AIR IONS	EXCESS ++
PARTICULATES	EXCESS (SMOKE)
ODOR	VARIED (B.O., Excreta, smoke)
RH	LOW - HIGH
TEMP	HIGH ΔT
OZONE	1 ppm ±
IR RADIATION	$\nearrow$<2μm
SPACE CHARGE	+

There are a variety of odors associated with stuffiness. The basic studies by Yaglou were with body odors and within a hospital we find that excretive, and cigarette smoke are two of the more objectionable kind of odors we find.

Relative humidity, either at the low end or at the high end, appears to be associated with stuffiness. At the low end we have the preponderance of reports saying that we are diminishing the mucus flow in the upper respiratory tree and we are diminishing vasculary action. Therefore, we are increasing the susceptibility to virus infections and causing all sorts of discomfort. At the high end we might have nasal dilation and usual stuffiness, including up the nasal passages.

High temperature differentials are also associated with stuffiness. This means a high vertical temperature gradation and will mitigate against ceiling panels.

Again, ozone is self explanatory. Infared radiation of less than 2 micrometers appears to be associated with stuffiness, largely because of its penetrating capacity into the human body and its warming effect. A few reports say that positive space charge is the cause of stuffiness. The reports do not discriminate space charge from an ion concentration.

What are defined as small ions are really charged molecules at fairly high speed (see Table 25).

Table 25. Definitions of air ions.

DEFINITIONS OF AIR IONS	
SMALL	CHARGED MOLECULES SPEED, 1-2 cm/sec/volt/cm
MEDIUM	LARGE MOLECULES - AITKEN NUCLEI SPEED . 02 cm/sec/volt/cm
LARGE	PARTICLES 0.1 - 10 μm WATER DROPLETS, CONDENSATION SPEED . 0005 cm/sec/volt/cm

(Schaeffer)

Medium sized ions, large molecules, are mostly water molecules that have not gained the status of particle size. Large particles, the .1 and 10 micrometer particles are water droplets, condensation, dust particles or cigarette smoke. The charge to mass is diminishing rapidly as the particles increase, and, therefore, the mobility is decreasing rapidly. Because the medium in large particles is so immobile, it is not easy to separate the effect of the particulates from ions. So most of the work done with air ions has to do with small ions.

Table 26 lists the effects of air ions. Briggs Philips did some work years ago and showed that positive air ions killed airborne bacteria. Really they didn't kill them as much as they acted to agglomerate the bacteria.

Table 26. Biological effects of air ions (positive, small).

SOURCES:	SHARAV, FOEHN, SANTA ANA, ETC. COSMIC RAYS, UV, R.I., HV, MAN
EFFECTS:	DRYNESS OF MUCUS MEMBRANE STUFFINESS IN ROOM KILL AIRBORNE BACTERIA DEPRESS CILIARY BEAT RATE BLOCK MOA ACTION INCREASE FREE 5-HT INCREASE FLU MORTALITY IN MICE SLOW ALPHA RYTHM
NO IONS	DEATH OF MICE

Perhaps the most important thing to me that hasn't been shown is that it hasn't been shown in animals because of the ions dropped, the MOA in animals, an increase from 5 Hydroxy temperature (5HT). Krueger has shown that flu mortality in mice has been accelerated by exposing them to positive ions. Another investigator has shown a slowing in the alpha rhythms.

Cosmic rays produce negative ions, ultraviolet, again produces both positive discharges and negative discharges, so do radioisotopes and high voltage discharge (see Table 20) Philips experiments showed that although he got some loss in viability with positive air ions in his airborne microns, the loss of viability using negative ions was even greater.

Table 27. Biological effects of air ions (negative, small).

SOURCES:	WATER FALLS, COSMIC RAYS, UV, RADIO ISOTOPES, HV DISCHARGE
EFFECTS:	ASTHMA RELIEF INCREASE IN CILIARY ACTION IMPROVED WELL BEING LOSS OF VIABILITY IN AIRBORNE MICROBES REDUCES FREE 5-HT IN ANIMALS STIMULATE MOA ACTION REDUCE ANXIETY SPEED ALPHA RYTHM SLOW ALPHA RYTHM DECREASE FLU MORTALITY IN MICE INCREASE MUCUS FLOW

Reducing the 5HT in animals is important. The 5HT is in your zero hormone, which does produce the next phenomena: anxiety. You have all heard that MOA inhibits happiness and that characteristic is attributed to the negative ions.

In *Science*, Krueger has recognized a great lack of experimental technic. It's difficult to measure a single quantity when you are talking about 400 or 500, maybe 5,000, small air ions and with these in an accelerating voltage of say 300 volts will induce a current of ten to the minus 17th ampheres. The room for error is considerable in that kind of measurement.

Effects of EM and ES fields are in our HVAC systems. We find this in our nuclear submarine condition because a nuclear submarine is nothing more than a large tin can of

machinery. At the top of Table 28 I relate the effects of extra low frequency, electromagnetic fields of less than 45 Hertz. The effects were on mice. The field strength is about 13,000 and that produced about .07 volts per centimeter and than's in experiments done by Krueger in support of Project Sanquine or Seafarer. As you see there were no teratogenic effects. The flu mortality wasn't changed and the growth rate was fairly regular. Although in the seventh generation of a litter of 12, eleven of the mice died. It has been stated by Weaver, that no field at all causes degeneration of man's rhythm because in the final analysis we are all subjected to the normal geomagnetic fields. This field can be restored with an AC field of about 2½ volts per meter at 10 Hertz. Ten Hertz is like a magic word because we find that 10 Hertz is also in the area where we can stimulate the alpha rhythm and if we have a pronounced 10 Hertz field we can be excited to telephathy, so I'm told.

Table 28. Effects of EM and ES fields.

ELF - EM (on mice) ca 0.13 GAUSS, 45 HZ ca. .07 V/cm.	NO TERATOGENIC EFFECTS NO SEROTONIN CHANGES FERTILITY UNCHANGED (6 gen) FLU MORTALITY UNCHANGED GROWTH RATE UNAFFECTED
E. S. FIELD (on humans) 12.5K @ CEILING	"STUFFY" ATMOSPHERE ASTHMA ATTACKS EXACERBATED

The electrostatic field on human health is about 4½ KV to provide sufficient atmosphere. In this, a group of about 15 asthmatics were put into a 12 KV field on the ceiling and sure enough the asthmatics attacks were exacerbated. Hauf and Weisenger indicated one to fifteen KV per meter seems to increase the reaction time and on the plant growth we have up

to 200 KV per meter, but really over a short field and 50 KV maximum electrostatic field showed an increase in barley growth. When it got over 50 KV there appeared to be some corona discharge back through the barley and the barley separated what seemed to be burns. The author claims they weren't burns but they looked like burns and apparently smelled like burns and from the pictures one could conclude that a blowtorch would have accomplished exactly the same thing.

I'm left with the conclusion that there is some effect from air ionization. I'm not sure what the effect is but I think the conclusion I would draw is that we should attempt to provide ventilating air which does not at least offer us a gross imbalance in any direction. The ventilating air we provide should be a reasonable simulation of good clean outside air.

Aesthetic Factors: Odors

Dr. Andrew Dravnieks

Odor is really a sensation, not a chemical compound. People will frequently talk about odors as if they were chemical compounds. The chemical stimuli are odorants or mixtures of odorants. These are moelcules which enter the nose and interact with the sensory system so we have a perception or a sensation of an odor.

Odors have two major sets of dimensions: 1) psychophysical or sensory, a description of sensation, and 2) analytical. In essense, if you take some mixture of odorants and analyze it you can produce an inventory of compounds, mention of the concentrations and have a tabulation of what's in the air. It's a good analytical description of the chemistry of the odor, but it does not reflect any description of the sensation. You have to know more about the relative concentrations needed to produce a specific odor sensation intensity before you can describe the resulting odor sensation. This is not yet possible in the present state of the art. Thus, the analytical dimensions are of importance only when you study odor sources; for instance, which components in odors originate from the room and which originate from people. In such cases, analytical work is useful. I will return to this at the end of my presentation.

In the present stage, odor measurements would have to be done using psychophysical means. In other words, by asking responses of people who think they smell something. What are the main psychophysical principles? One is the odor intensity or how strong it smells when you enter a room. You don't know

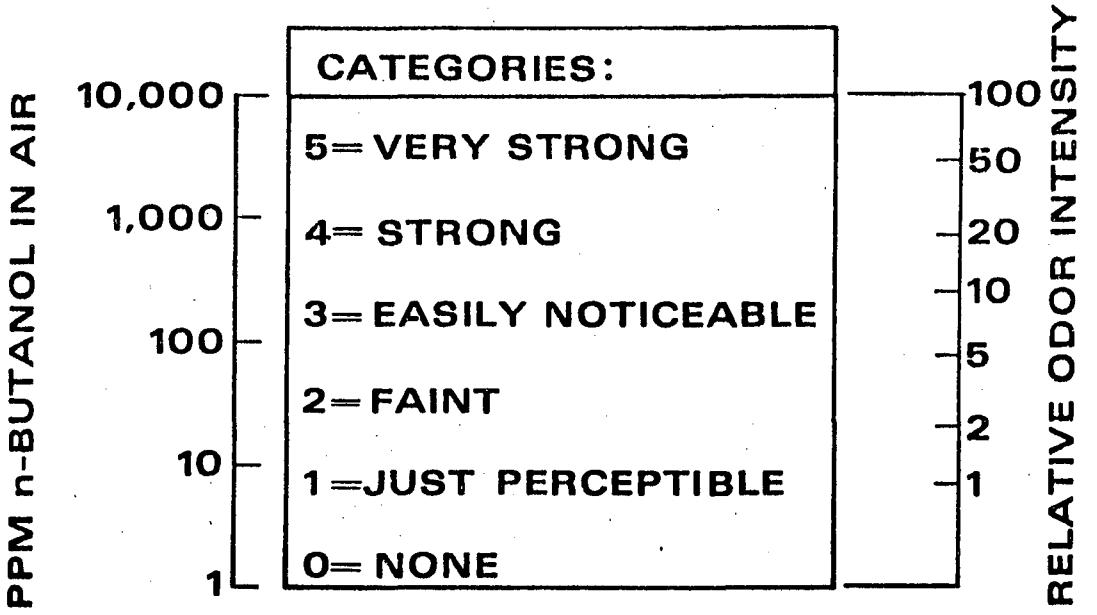
how much ventilation is required to reduce odor. All we know is that the odor is weak or strong. This is the odors perceived intensity. There could be odors at the same intensity but they obviously may smell differently: medicinal type odors, or perspiration odor. Furthermore, the odor quality is related to the unpleasantness of the so called hedonic tone of the odor. The odor may be pleasant or unpleasant to varying degrees or the odor can be neither and so therefore it is neutral.

Finally, when you talk about odor intensity of a sample and you start diluting the odorous air, the odor sensation decreases and at some point the intensity becomes so low that we have difficulty telling if there is an odor or not. It reaches the threshold intensity values and at that point one talks about odor threshold concentration. The odor threshold concentration is not a magic number like boiling point. It's statistically distributed among the people. It's common to find that when you test a large group of people the differences in sensitivity may be as high as almost two orders of magnitude. When you start reducing the odorant concentration and try to relate it to odor thresholds, you really have to decide what dosage is critical: Is it one where 50 percent of the people smell it and 50 percent don't or where 5 percent detect it and 95 percent do not? This is similar to drug research and other response research. These are the odor intesity categories.

I will start with the first dimension, the perceived odor intensity measure (see Table 29) One method of measureing odor intensity is to give people a scale; for instance, a typical scale is zero (no odor) to five (very strong odor. These are the odor intensity categories. To solve the difficulties associated with this means of measurement the American Socity of Testing and Materials (ASTM) E18 Sensory Evaluation Committee established a task force to study how

to measure the odor intensities and how to reference those intensities.

Table 29. Scale for measuring perceived odor intensity.



They arrived at a system that was tested in a round robin exercise in comparisions with the category scale. The recommendation was for a butanol concentration scale for a reference.

Figure 31 is an illustration of the butanol scale. The principle is that you have essentially eight nozzles from which the butonal vapor at different concentrations is supplied. The weakest concentration usually is two to four times above mean odor threshold of butanol and hasa slightly noticeable odor. The highest concentration is saturated butanol vapor diluted by a factor of five or about 2,000 parts per million of butanol in air. The step-up of concentrations from port to

port is by a factor of two. People smell the unknown odor and compare it to the butanol scale. They would say, for example, it smells as strong as port No. 4. Thus, today this particular odor at some particular place was as strong as 100 parts per million of butanol. This seems to be much more useable than the category scale.

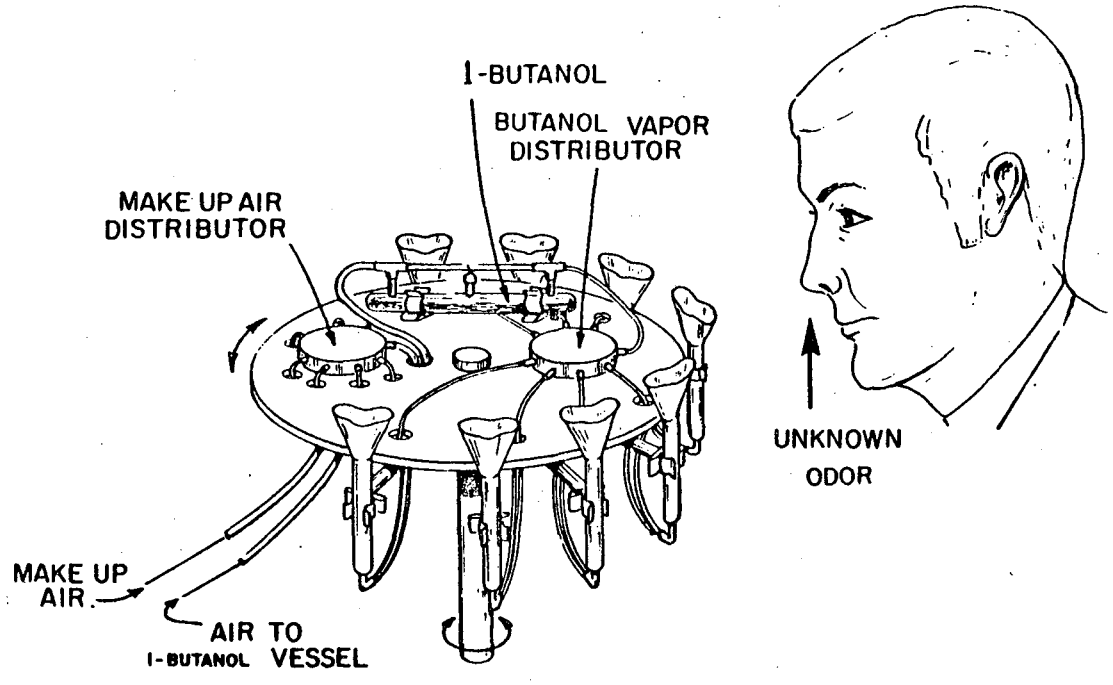


Figure 31. Butanol scale.

The figures do not indicate how much stronger one odor is in respect to another. If an odor is strong or a 4 on a category scale and another odor is 2, which is faint, you cannot surmise that the stronger smell is twice as strong as faint to people. There is a much larger difference in the perceived intensity. The function which connects the perceived odor intensities is $S = KC^n$, $\log S = k + n \log C$. It's called psychophysical power, sometimes referred to as Stevens Law. Basically it says that the perceivable intensity S (how

strong you feel it without knowing anything else) is proportional to the concentration of odor to the power n. Different odorants have different k values and different n values. The significant item here is that n, the exponent, is not unity, it's a fraction of unity. It tends to be between .2 and .7, but there are some cases beyond these limits.

Figure 32 is the most basic plot for developing the particular function for a particular odorant. Suppose we look at the propionic acid plot. In this case people are given to smell certain concentrations (0.005 on X-axis) of propionic acid and are told to consider that intensity equal to 10. They are then asked to smell weaker concentrations and provide a proportionate smaller number. What this plot will give you is the parameters for a particular psychophysical function.

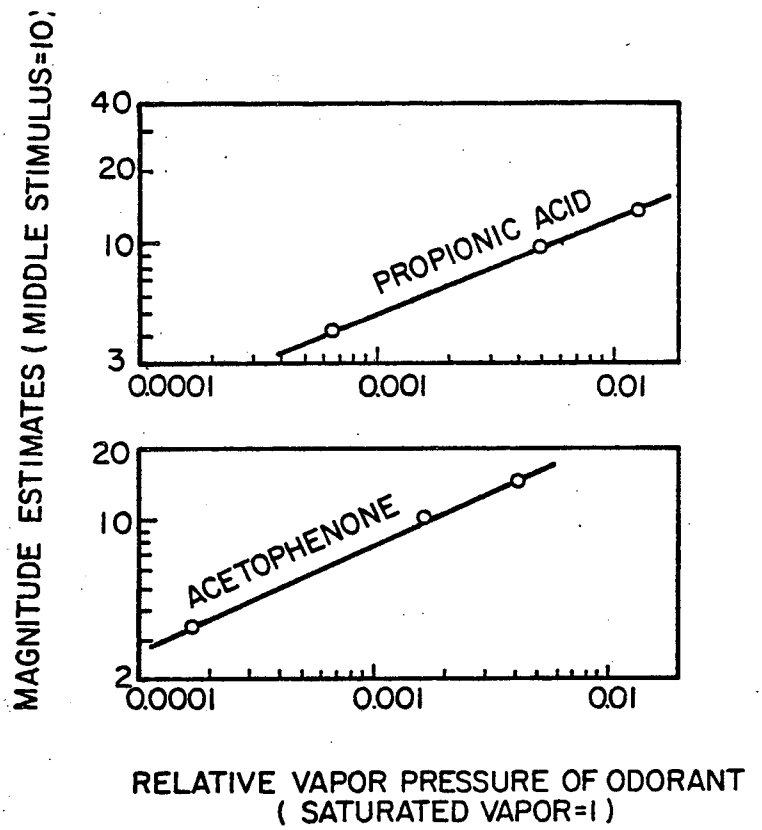


Figure 32. Relative vapor pressure of odorant.

Similar functions were obtained for butanol by three different groups: Natick Research Lab, an Army Research Lab; John Pierce Foundations, and IIT Research Institute. With all data combined the mean n was .66. These groups and Amos Turk, an expert on odorous air pollution proposed a scale based on butanol, postulating that 250 parts per million of butanol has an odor intensity of 10. If you plug C, 250 parts per million, and S is 10 and n is .66, you get the coefficient for k of the above equation (small k = 0.261).

This is being increasingly used by people in air pollution research and in our labs to measure intensities versus butanol and to convert these intensities into the S scale. The S scale now behaves so that if you measure and obtain S equals 5 for odor A and 10 for odor B, an average person would feel that S = 10 would smell to people twice as strong than S = 5. This is very approximate, but better than the general category scale. The righthand side of figure shows the S scale. This function means, that suppose that n is .33, you have to reduce a concentration by a factor of 8 before you feel that the odor has beomce twice as weak.

Such a slow response to the concentration of odorants has very significant repercussions in ventilation requirements. If you have odorous air and if you haven't decreased the odor below the threshold, you can decrease the ventilation rate by a factor of say 4 and people will barely notice the change. It has to be clearly realized that it doesn't make much sense to increased a noticeable odor.

The ventilation rate would have to be increased much more to get it down to the odor threshold region. There is some controversy whether this function hold down to threshold and to the sub-threshold levels. My first assumption is that it does hold,

for simplicity, unless somebody proves differently. Some believe it becomes linear, with n = 1.

Figure 33 represents the psychophysical functions for several types of odorants. For instance, you can compare hexadienal, has a grease or grassy type of fatty odor and so a rather common component of cooking odors and with hexylamine, which has a fishy type odor. These two lines cross. If you increase ventilation the perceived odor intensity of the hexadienal odor would be reduced more markedly. For the hexylamine odor nothing much seems to be happening but it is still substantially there. On the same graph you may visualize extrapolating these plots to the scale points below one unit on the right side, relative to odor intensity.

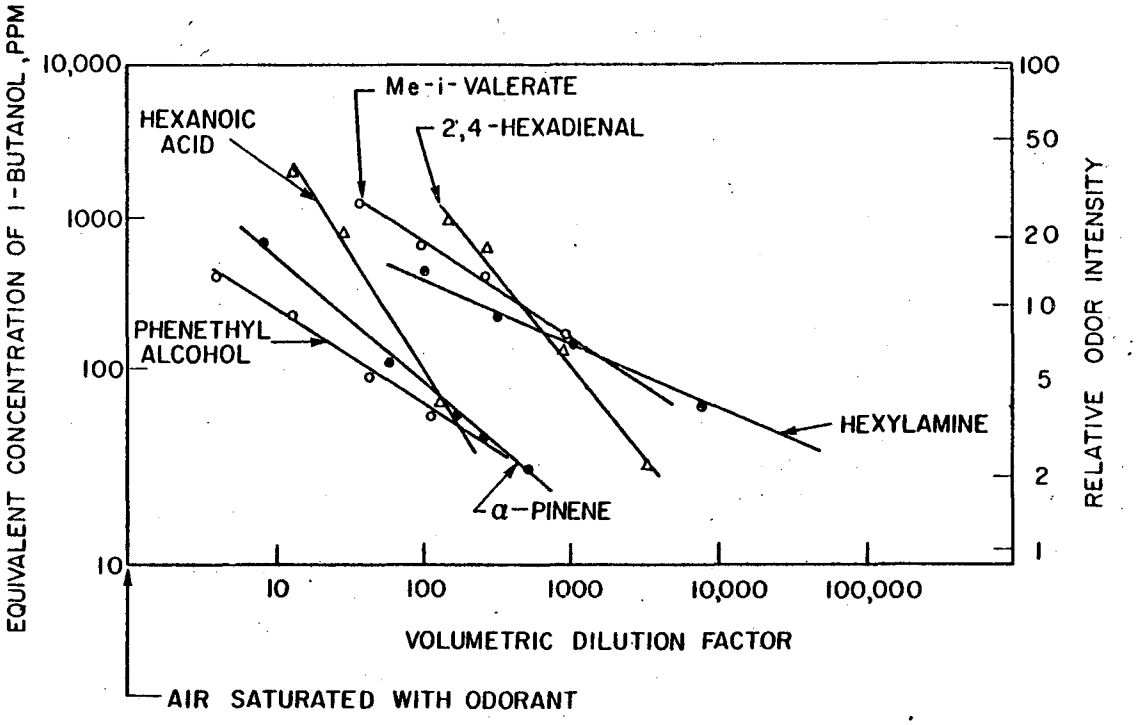


Figure 33. Psychophysical functions for several types of odorants.

The numbers are proportional to the sensory intensity. If the hexylamine line was continued below the odor threshold, it would be, theoretically, decreasing less rapidly than the hexadienal line. When we talk about 50 percent threshold, it means that 50 percent of the individuals will detect it and 50 percent of the individuals will not. Suppose I decreased the concentrations below threshold. It does not mean we quit detecting odor all together, we just detect the odor with less frequency. Usually, when people detect some odors, only several times an hour, as far as they are concerned, there still has been an odor. Therefore, the odorants with lesser slope in this plot are more obnoxious even if they are hedonically similar because there is more chance to detect such odors at concentrations even the 50 percent threshold. This relates to the pervasiveness of odors. It doesn't seem to go away with dilution.

Another type of pervasiveness is based on absorption. Some odors can be absorbed on upholstery and walls so strongly that it takes a large amount of time to get them off. This is a physico-chemical type of pervasiveness.

Let's discuss the odor threshold measurements. What is the ultimate dilution to get rid of an odor? Thresholds are actually the first things people started measuring on odors. It was believed that odor strength could be measured in terms of the odor threshold multiples. The plot in Figure shows that it is not quite so. Some odors 10 times above their threshold concentrations may be quite strong while other odors 10 times above the threshold not quite as strong. For ventilation purposes, it's still quite useful to know the threshold concentrations even if perceived odor intensities are not measured.

Until 10 or 15 years ago, people were very positive about odor measurements with people just deciding if it smells or not.

More recently, signal detection theory was related to psychophysics and it became quite clear that when you asked for such judgments all kinds of factors determine the response (see Table 30).

Table 30. Gradations of judgment.

VERY SURE
SOMEWHAT SURE
NOT SURE
SOMEWHAT SURE THAT NONE
VERY SURE THAT NONE

CRITERION DETERMINES

YES/NO BOUNDARY

When people respond, they combine what the nose seems to tell them with other considerations such as how fast a person jumps to conclusions. In order to separate the judgment criteria from the sensory sensitivity of the olfactory system you have to have data collection systems based on signal detection theories. You have to obtain humdreds and hundreds of judgments otherwise you cannot isolate these two factors: the sensitivity and the criterion of the judgment.

For practical purposes there should be some short cuts. One is the use of forced choice methods. For instance, you give people two stimuli, one contains ordor and another one doesn't contain odor and ask them which is odorous. He has

to respond or at least guess. Then much of the criterion effect is deleted. More recently there is an increasing trend toward the odor threshold measurements method in which multiple choice presentations are made. The ASTM has a test where the odorous air is diluted in syringes and then smelled. This year it has been changed into a forced choice: two syringes are given, one with blank air and another with an odorized air. The syringe test is not very good because there is an adsorption of odorants of the walls of the syringe. Dynamic dilution systems are preferred when thresholds are determined. There are systems where the odor sample flows through tubing at some controlled rate and is diluted by mixing with a regulated flow of air to get various dilutions. Figure 34 utilizes cups with three glass nozzles for smelling. Two of the nozzles contain plain air from the room where the test is made.

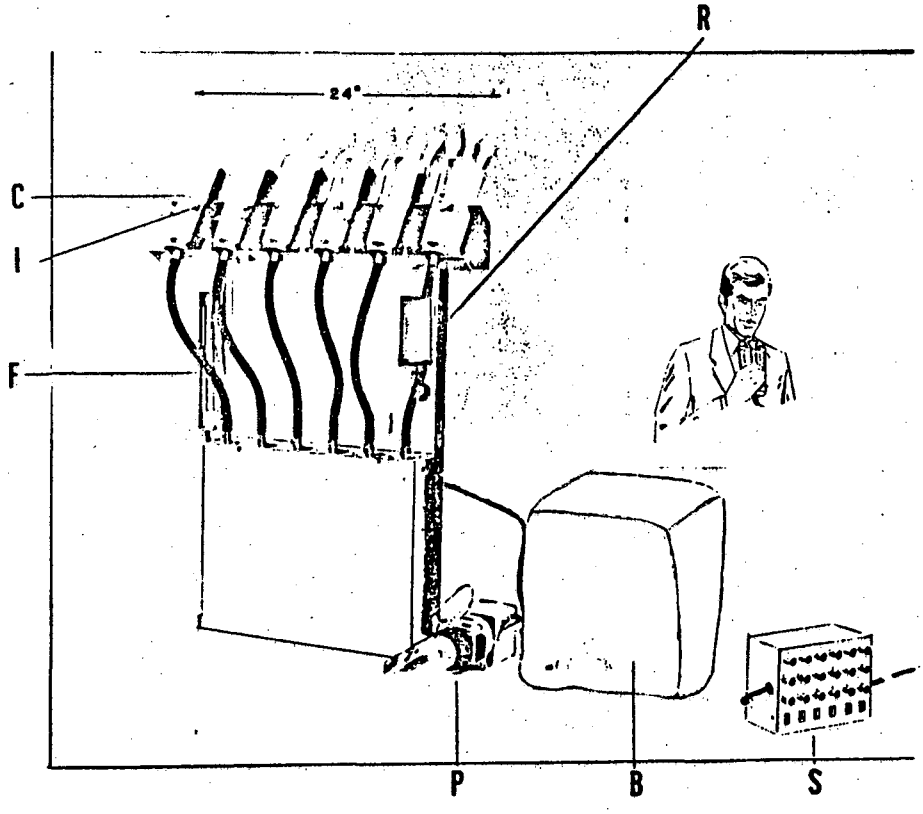


Figure 34. Device that utilizes triangle test for measuring odors.

One of the three nozzles in each cup contains odor samples diluted to a certain extent with six cups holding three nozzles each permit access to six different dilution levels. On the left is the most diluted sample. The next is three times more concentrated and so on. The odorous sample is delivered either directly from some system such as an odorous room, or else it's stored in some bag and then pumped or pressed from the bag into this device. The internal plumbing provides for various dilutions.

To produce data you express the threshold dilution in terms of logarithmic dilution of the factors then the standard deviation of repeated panel means (9 panelists) is about 0.1 log units. Triangle presentation design is possible iwth other types of olfactometers as well.

Two odors may have the same threshold dilution values and even the same intensities, but present different annoyance potentials, since they differ in the unpleasantness or pleasantness. How do you rate the pleasantness and unpleasantness? We have experimented with all kinds of scales. The classical scale is simply zero to seven; for instance, zero is very pleasant, seven is unpleasant and neutral is in the middle. Psychophysicists consider judgments of pleasantness and unpleasantness as a two-level judgment. First, people decide that the odor is pleasant or unpleasant or neutral. After deciding whether it's pleasant or unpleasant they also decide how pleasant or unpleasant it is. It's really categorizing and then mapping the dimension in the applicable category. The resulting category scale has zero in the middle and plus three in the top for the pleasant and minus three on the bottom for the unpleasant odors.

A problem with category scales is that they have an obvious ceiling. Open-ended scales are preferred and actually the

in psychophysics seems to have people make free, open-ended judgments with as little constraint as possible and to use modern statistical means to translate these judgments onto a scale. One means of making a judgment without an obvious ceiling is to ask if the odor is pleasant or unpleasant. A random number is assigned to indicate how unpleasant or pleasant an odor is. With a number of judgments a mean value results. Such a method is known as a magnitude estimate. I'm concerned with the use of a number scale as a person tends to remember and carrying over this number to other exercises.

Figure 35 is an example of a scale we now use. When people smell something we ask them to decide whether it's pleasant, neutral or unpleasant.

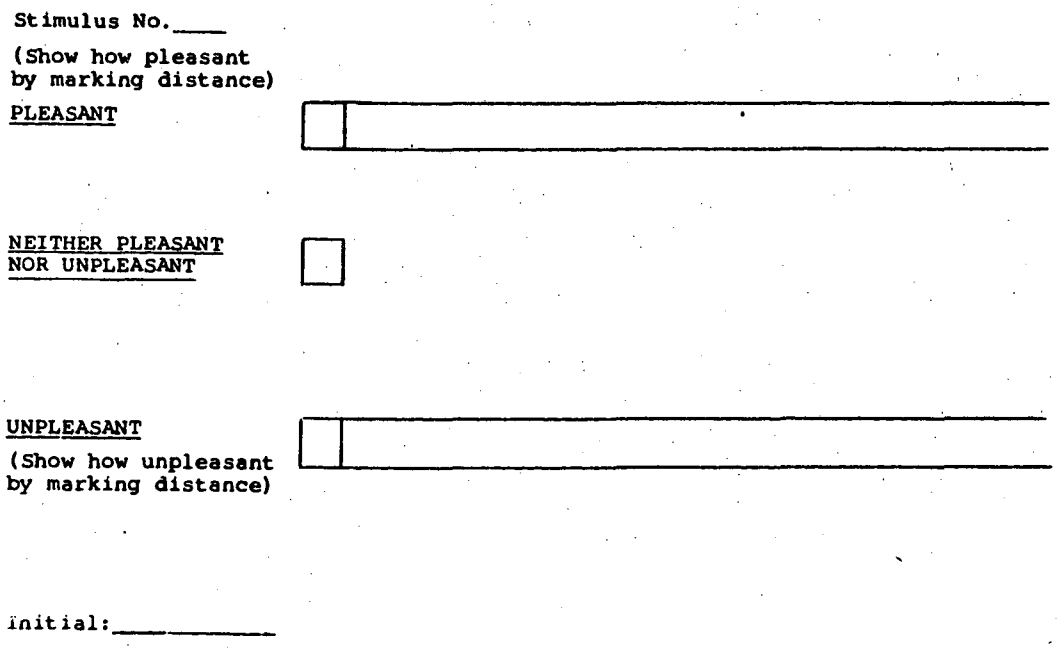


Figure 35. Open-ended system of measuring odors.

The pleasant and unpleasant categories have a length of bar to mark off how unpleasant or how pleasant an odor is. For practical reasons we use a system which permits some normalizing where say two inches is the equivalent of moderate unpleasantness. A mark of four inches is defined as 100 units of unpleasantness. Two inches marked off would mean $\frac{2}{4} \times 100 = 50$ so this odor was 50 units unpleasant to me. There is a category scale inside the bar scale, but it's not obvious and it's somewhat open ended. Members of the panel are distributed in two categories: people who proportion and people who stick with the instructions. In later work we used a box with pullable flexible steel rulers.

We haven't done many measurements on indoor odors with these scales, but we have done a lot of work with air pollution odors from outside sources (see Figure 36).

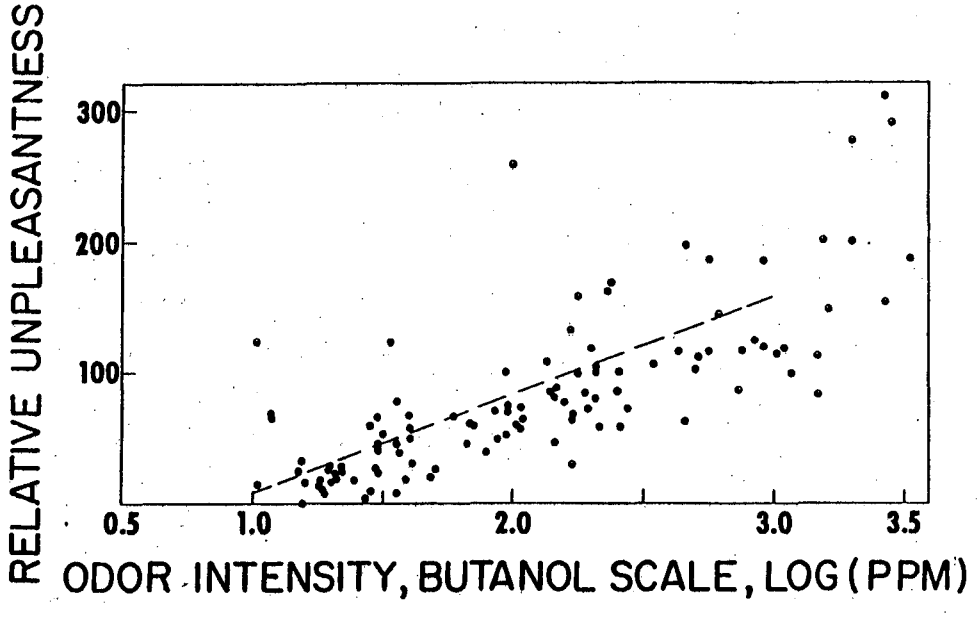


Figure 36. Measurement of air pollution odors from outside sources.

This figure represents air pollution odors from industrial sources. All are unpleasant. The dashed line is a regression line and it permits looking at each new sample and comparing that new sample with the other types of emissions.

When we deal with odor sources we have to consider the emission strength. In industrial air pollution work emission strength is measured in terms of the fresh air volume which is needed per minute to reduce the odors down to the threshold values. With respect to the odors in hospitals, it would be quite useful to measure the odor emission strength of typical indoor odor sources: cigarettes, pipes, cigars, maybe an elimination process, lunch trays or changing the bed after an incontinence.

If the emissions are measured in terms of demand in cubic meters of air you can have engineering values which say that if all of these odors get mixed together what is the total load imposed on the ventilation system. It's unwise to let all odors go into the general ventilation system. It's very much easier to treat these odors at the source. Full ventilation is not needed all the time but at certain times you need intense ventilation for odor removal. As systems get more and more closed you may use active carbon to remove odors locally. If you put so many cubic meters of odorous air through a carbon filter, of specific thickness and linear flow rate -- how much fresh air do you substitute by this kind of operation? Of course the filter requires energy but you may need less energy for bringing in outside air. Such approaches have to be developed gradually. It is a useful effort to determine where we stand with odor control in hospitals.

One would think we ought to make all odors pleasant and have everything smell like a rose but, odors can get associated

with unpleasant situations. Sensory impacts tend to combine visuals, odors and so on. For example, in Sweden some complaints about odorous air pollution were closely associated with zones where you could see the chimney where the odors were emitted. Where the people could not see the chimneys the complaints where fewer in spite of the fact that there was no reason why the odor should have reached that location less frequently.

Use of air fresheners or pleasant odors can have temporary effects. There are objections that you do not reduce air pollution but you increase air pollution with such materials. Some people may have allergies that are aggravated by fresheners. Manufacturers can't even tell what the exact chemical composition is of a freshener. Relatively non-expensive raw materials from various sources are put together to find out what mixture seems to cover up certain types of malodors. They say these are natural products and not harmful, but many natural products can be harmful. Air fresheners are not a long-range solution.

There is really few differences between people in opinions of what odors are pleasant or unpleasant. There is more divergence in opinions of pleasantness of odors. There are always some people who consider an odor to be unpleasant that most other people think is pleasant.

In the hospital situation pleasant odors have very limited application. Even flowers can be a problem as many people are reminded of funeral parlors by flowers. Figure 37 is a means of relative hedonic scale. We conducted experiments using about 20 panelists and 28 different odorants. On top is vanillin (V), the most pleasant odor, and on the bottom is isovalleric acid (I), the most unpleasant odor. These are

mean values from four different presentations over two years. The length of the segment is the standard deviation developed from repeated presentations. If we take our scale and compare it with some measurements done by Wosha at the University of California, many years ago, there is a statistical ratio agreement. It should be possible to produce a hedonic scale of general usefulness. A plot of standard deviations is at the top of Figure 37 . The standard deviation does not seem to be specifically related to unpleasant, or pleasant, or inbetween. The strongest, highest standard deviation was citral (W) and the smallest standard deviation was for ammonia (3).

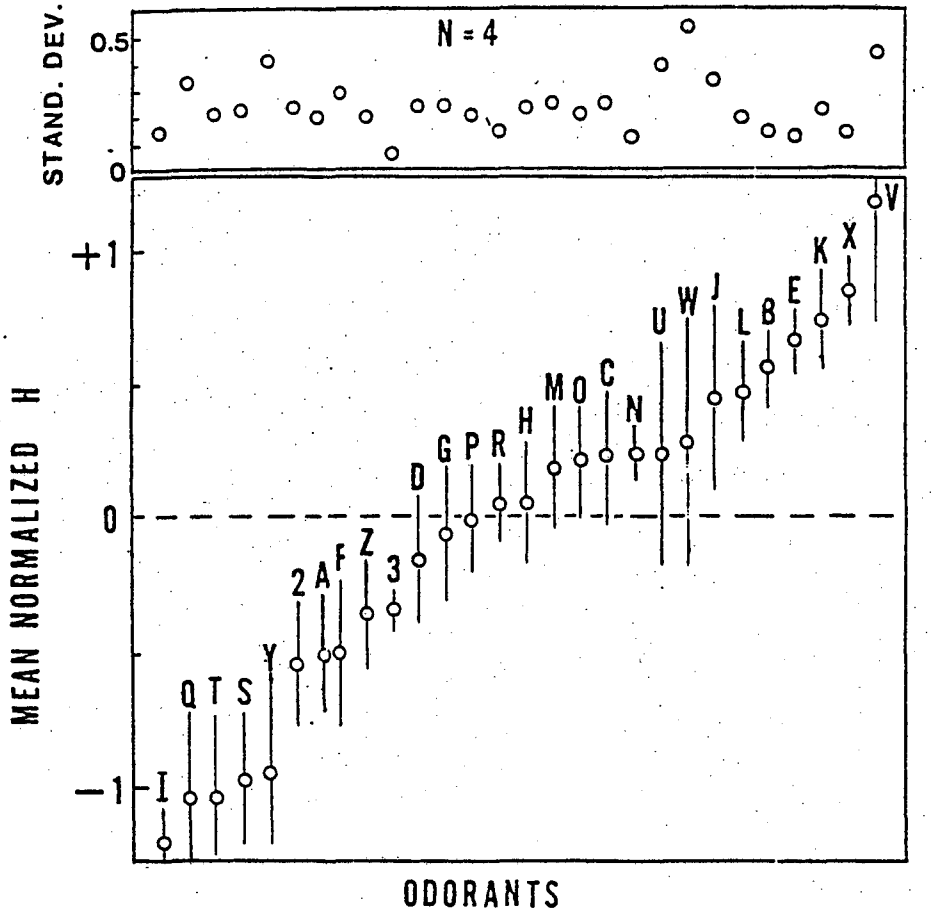


Figure 37. Relative hedonic scale.

Odor character or quality can be described (see Table 31) by an essay or through content of various odor notes or by a comparison to reference odorants. The descriptor method is logistically the simplest. It also is an approach that can be easily analyzed and is known as multidimensional scaling. Harper in England developed a 44 descriptor scale for food odors. People smell an odor sample and describe on a zero to five category scale the applicability of each of these descriptors to the odor sample. This results in a profile on each odor in 44 dimensions.

Table 31. Means of describing odor character or quality.

ODOR QUALITY (CHARACTER)

OPEN DESCRIPTION
MULTIDIMENSIONAL SCALING
SEMANTIC (WORDS)
ODORANT REFERENCES

When we did our work on pollution odors we found that in many cases profiles of different odors on Harper's scale were almost the same although the odors were distinctly different. We increased the number of descriptors to 136. There was a round robin exercise conducted by ASTM E18 Committee using this expanded descriptor scale. We found that really we need a few more descriptors like "alcoholic." Finally, we came out with a scale of 146 descriptors (see Table 37). There are several approaches to the utilization of the descriptor scales. The ASTM task force prepared a report to be published in *Chemical Senses and Flavor*.

Table 32

1	2	3	4	5	6	7	8	9	10	11	12
						1					
SAMPLE DESIGNATION							PANEL CODE			PANELIST	

(Col. 1–6, 8–10: letters or numbers. Col. 11–12: numbers only.)

ODOR QUALITY EVALUATION

* SMELL SAMPLE. YOU CAN RE-SMELL IT AS NEEDED FOR EVALUATION.

** GO THROUGH LIST BELOW. FOR EACH DESCRIPTOR, *ENCIRCLE* THAT SCORE NUMBER WHICH BEST CHARACTERIZES THE *DEGREE OF PRESENCE* OF THAT ODOR NOTE IN THE SAMPLE ODOR. IF ABSENT, *DO NOT ENCIRCLE ZERO.*

*** INITIAL OR SIGN, AND DATE.

Initial or Signature . . . . . Date . . . . .

MEANING OF THE ODOR QUALITY SCALE:

ABSENT	SLIGHTLY		MODERATELY		EXTREMELY
0	1	2	3	4	5

Index	*DESCRIPTOR*	*SCORE*	*Index*	*DESCRIPTOR*	*SCORE*
001	FRAGRANT	0 1 2 3 4 5	031	OILY, FATTY	0 1 2 3 4 5
002	SWEATY	0 1 2 3 4 5	032	LIKE MOTHBALLS	0 1 2 3 4 5
003	ALMOND-LIKE	0 1 2 3 4 5	033	LIKE GASOLINE, SOLVENT	0 1 2 3 4 5
004	BURNT, SMOKY	0 1 2 3 4 5	034	COOKED VEGETABLES	0 1 2 3 4 5
005	HERBAL, GREEN, CUT GRASS	0 1 2 3 4 5	035	SWEET	0 1 2 3 4 5
006	ETHERISH, ANAESTHETIC	0 1 2 3 4 5	036	FISHY	0 1 2 3 4 5
007	SOUR, ACID, VINEGAR	0 1 2 3 4 5	037	SPICY	0 1 2 3 4 5
008	LIKE BLOOD, RAW MEAT	0 1 2 3 4 5	038	PAINT-LIKE	0 1 2 3 4 5
009	DRY, POWDERY	0 1 2 3 4 5	039	RANCID	0 1 2 3 4 5
010	LIKE AMMONIA	0 1 2 3 4 5	040	MINTY, PEPPERMINT	0 1 2 3 4 5
011	DISINFECTANT, CARBOLIC	0 1 2 3 4 5	041	SULPHIDIC	0 1 2 3 4 5
012	AROMATIC	0 1 2 3 4 5	042	FRUITY (CITRUS)	0 1 2 3 4 5
013	MEATY (COOKED, GOOD)	0 1 2 3 4 5	043	FRUITY (OTHER)	0 1 2 3 4 5
014	SICKENING	0 1 2 3 4 5	044	PUTRID, FOUL, DECAYED	0 1 2 3 4 5
015	MUSTY, EARTHY, MOLDY	0 1 2 3 4 5	045	WOODY, RESINOUS	0 1 2 3 4 5
016	SHARP, PUNGENT, ACID	0 1 2 3 4 5	046	MUSK-LIKE	0 1 2 3 4 5
017	CAMPHOR LIKE	0 1 2 3 4 5	047	SOAPY	0 1 2 3 4 5
018	LIGHT	0 1 2 3 4 5	048	GARLIC, ONION	0 1 2 3 4 5
019	HEAVY	0 1 2 3 4 5	049	ANIMAL	0 1 2 3 4 5
020	COOL, COOLING	0 1 2 3 4 5	050	VANILLA-LIKE	0 1 2 3 4 5
021	WARM	0 1 2 3 4 5	051	FECAL (LIKE MANURE)	0 1 2 3 4 5
022	METALLIC	0 1 2 3 4 5	052	FLORAL	0 1 2 3 4 5
023	PERFUMERY	0 1 2 3 4 5	053	YEASTY	0 1 2 3 4 5
024	MALTY	0 1 2 3 4 5	054	CHEESY	0 1 2 3 4 5
025	CINNAMON	0 1 2 3 4 5	055	HONEY-LIKE	0 1 2 3 4 5
026	POPCORN	0 1 2 3 4 5	056	ANISE (LICORICE)	0 1 2 3 4 5
027	INCENSE	0 1 2 3 4 5	057	TURPENTINE (PINE OIL)	0 1 2 3 4 5
028	Cantaloupe, Honey Dew MELON	0 1 2 3 4 5	058	FRESH GREEN VEGETABLES	0 1 2 3 4 5
029	TAR-LIKE	0 1 2 3 4 5	059	MEDICINAL	0 1 2 3 4 5
030	EUCALYPTUS	0 1 2 3 4 5	060	ORANGE (FRUIT)	0 1 2 3 4 5

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Table 32

KEYPUNCHER: Enter Columns 1–12 as coded in at the left. Beginning with the Column 13, enter indexes (three columns) and encircled scores (one column) in a continuous fashion, but only for those lines where a score is encircled. If continuation cards needed, repeat Columns 1–12 on each card.

Index	DESCRIPTOR	SCORE	Index	DESCRIPTOR	SCORE
061	BUTTERY (FRESH)	0 1 2 3 4 5	104	HOUSEHOLD GAS	0 1 2 3 4 5
062	LIKE BURNT PAPER	0 1 2 3 4 5	105	PEANUT BUTTER	0 1 2 3 4 5
063	COLOGNE	0 1 2 3 4 5	106	VIOLETS	0 1 2 3 4 5
064	CARAWAY	0 1 2 3 4 5	107	TEA-LEAVES-LIKE	0 1 2 3 4 5
065	BARK-LIKE, BIRCH BARK	0 1 2 3 4 5	108	STRAWBERRY-LIKE	0 1 2 3 4 5
066	ROSE-LIKE	0 1 2 3 4 5	109	STALE	0 1 2 3 4 5
067	CELERY	0 1 2 3 4 5	110	CORK-LIKE	0 1 2 3 4 5
068	BURNT CANDLE	0 1 2 3 4 5	111	LAVENDER	0 1 2 3 4 5
069	MUSHROOM-LIKE	0 1 2 3 4 5	112	CAT-URINE-LIKE	0 1 2 3 4 5
070	WET WOOL, WET DOG	0 1 2 3 4 5	113	PINEAPPLE (FRUIT)	0 1 2 3 4 5
071	CHALKY	0 1 2 3 4 5	114	FRESH TOBACCO SMOKE	0 1 2 3 4 5
072	LEATHER-LIKE	0 1 2 3 4 5	115	NUTTY (WALNUT, ETC.)	0 1 2 3 4 5
073	PEAR (FRUIT)	0 1 2 3 4 5	116	FRIED CHICKEN	0 1 2 3 4 5
074	STALE TOBACCO SMOKE	0 1 2 3 4 5	117	WET PAPER-LIKE	0 1 2 3 4 5
075	RAW CUCUMBER-LIKE	0 1 2 3 4 5	118	COFFEE-LIKE	0 1 2 3 4 5
076	RAW POTATO-LIKE	0 1 2 3 4 5	119	PEACH (FRUIT)	0 1 2 3 4 5
077	MOUSE-LIKE	0 1 2 3 4 5	120	LAUREL LEAVES	0 1 2 3 4 5
078	BLACK PEPPER-LIKE	0 1 2 3 4 5	121	BURNT MILK	0 1 2 3 4 5
079	BEAN-LIKE	0 1 2 3 4 5	122	SEWER ODOR	0 1 2 3 4 5
080	BANANA-LIKE	0 1 2 3 4 5	123	SOOTY	0 1 2 3 4 5
081	BURNT RUBBER-LIKE	0 1 2 3 4 5	124	CRUSHED WEEDS	0 1 2 3 4 5
082	GERANIUM LEAVES	0 1 2 3 4 5	125	RUBBERY (NEW RUBBER)	0 1 2 3 4 5
083	URINE-LIKE	0 1 2 3 4 5	126	BAKERY (FRESH BREAD)	0 1 2 3 4 5
084	BEERY (BEER-LIKE)	0 1 2 3 4 5	127	OAK WOOD, COGNAC-LIKE	0 1 2 3 4 5
085	CEDARWOOD-LIKE	0 1 2 3 4 5	128	GRAPEFRUIT	0 1 2 3 4 5
086	COCONUT-LIKE	0 1 2 3 4 5	129	GRAPE-JUICE-LIKE	0 1 2 3 4 5
087	ROPE-LIKE	0 1 2 3 4 5	130	EGGY (FRESH EGGS)	0 1 2 3 4 5
088	SEMINAL, SPERM-LIKE	0 1 2 3 4 5	131	BITTER	0 1 2 3 4 5
089	LIKE CLEANING FLUID (Carbona)	0 1 2 3 4 5	132	CADAVEROUS, Like Dead Animal	0 1 2 3 4 5
090	CARDBOARD-LIKE	0 1 2 3 4 5	133	MAPLE (AS IN SYRUP)	0 1 2 3 4 5
091	LEMON (FRUIT)	0 1 2 3 4 5	134	SEASONING (FOR MEAT)	0 1 2 3 4 5
092	DIRTY LINEN-LIKE	0 1 2 3 4 5	135	APPLE (FRUIT)	0 1 2 3 4 5
093	KIPPERY (SMOKED FISH)	0 1 2 3 4 5	136	SOUPY	0 1 2 3 4 5
094	CARAMEL	0 1 2 3 4 5	137	GRAINY (AS GRAIN)	0 1 2 3 4 5
095	SAUERKRAUT-LIKE	0 1 2 3 4 5	138	CLOVE-LIKE	0 1 2 3 4 5
096	CRUSHED GRASS	0 1 2 3 4 5	139	RAISINS	0 1 2 3 4 5
097	CHOCOLATE	0 1 2 3 4 5	140	HAY	0 1 2 3 4 5
098	MOLASSES	0 1 2 3 4 5	141	KEROSENE	0 1 2 3 4 5
099	ALCOHOL-LIKE	0 1 2 3 4 5	142	NAIL POLISH REMOVER	0 1 2 3 4 5
100	DILL-LIKE	0 1 2 3 4 5	143	FERMENTED (Rotten) FRUIT	0 1 2 3 4 5
101	CHEMICAL	0 1 2 3 4 5	144	CHERRY (BERRY)	0 1 2 3 4 5
102	CREOSOTE	0 1 2 3 4 5	145	VARNISH	0 1 2 3 4 5
103	GREEN PEPPER	0 1 2 3 4 5	146	SOUR MILK	0 1 2 3 4 5

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It seems that to completely describe a room odor it is desirable to define the emission rates of odor from the sources within the room and to characterize its perceived intensity. It is desirable to know its odor dilution threshold; its relative pleasantness or unpleasantness and its character, and (what it smells like). If it smells very characteristically, somehow that means it has really more annoyance potential. People can recognize this particular odor more distinctly if it's associated with the hospital situation. If descriptors scatter all over the place, and none is rated high, it's like a white noise. Such an odor does not hit you as a piercing noise or some other annoying situation, it is just everything for everyone and not very characteristic.

Tools exist to measure sensory properties of odors, but there is not enough data base to seek out the most suitable tools. However, even with the present tools engineering values maybe obtained for various odor situations and various types of odor sources in hospitals.

Odors result from complicated mixtures of odorants. It is needed to find out which odorants are principally responsible for the entire odor. Typically such work is done by using the odorogram approach where you take a sample of odorous air, either at the source or from a room, concentrate it and then inject it into the gas chromatograph. Suppose you have a mixture of eight different substances that travel through a long tubing by means of helium or nitrogen flow. The tubing contains some greases or oils on the walls or powder packed into the tubing. As the many different substances in one package travel through the tube they travel at different speeds determined by their vapor pressure and solubilities in the coating film. The substances exit from the other end of the tube spaced in time and they produce a gas chromatograph. A detector

detects the substances as they come out and produces a record in which substances are represented by peaks. Each peak responds to one substance but sometimes may represent several substances together. The exit from the gas chromatograph split and part is divided to a smelling nozzle where you can smell when the peaks appear and note that one smells like a rose, another like sweat and so on. An odorogram of the perspiration odor is shown in Figure 38. Perspiration was collected from some 50 people. It was pooled and incubated in a glass vessel so this is rather a potent odor.

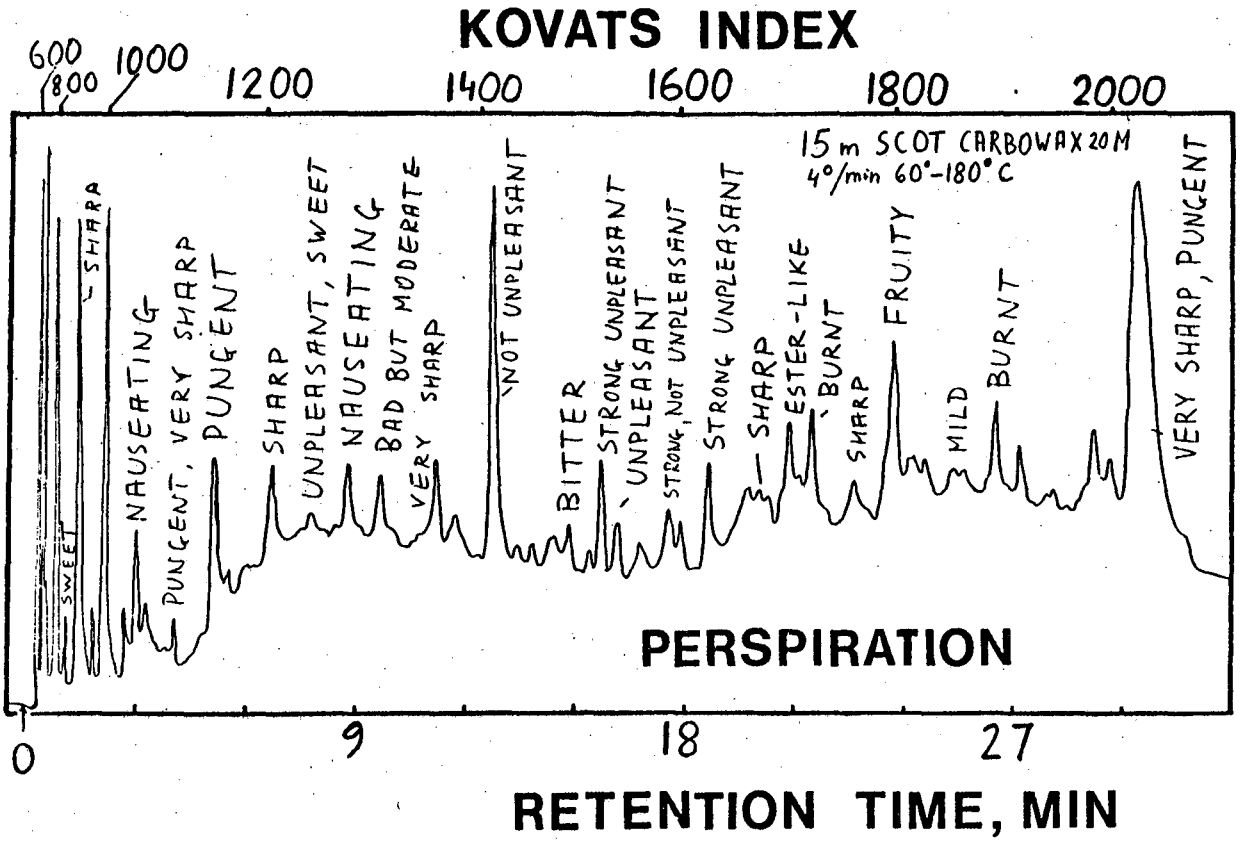

Figure 38. Odorogram of perspiration odor.

Such means for odor control as absorption or scrubbing can act differently on different compounds. The odorogram process indicates changes even without knowing what chemicals these are.

Figure 39 is a composite odorogram for tobacco smoke odors with a number of odors. Those shown with arrows are carrying quite a bit of odor. Also in this odorogram process, the gas chromatographic peaks, which are not accompanied with significant odors, are below their odor threshold.

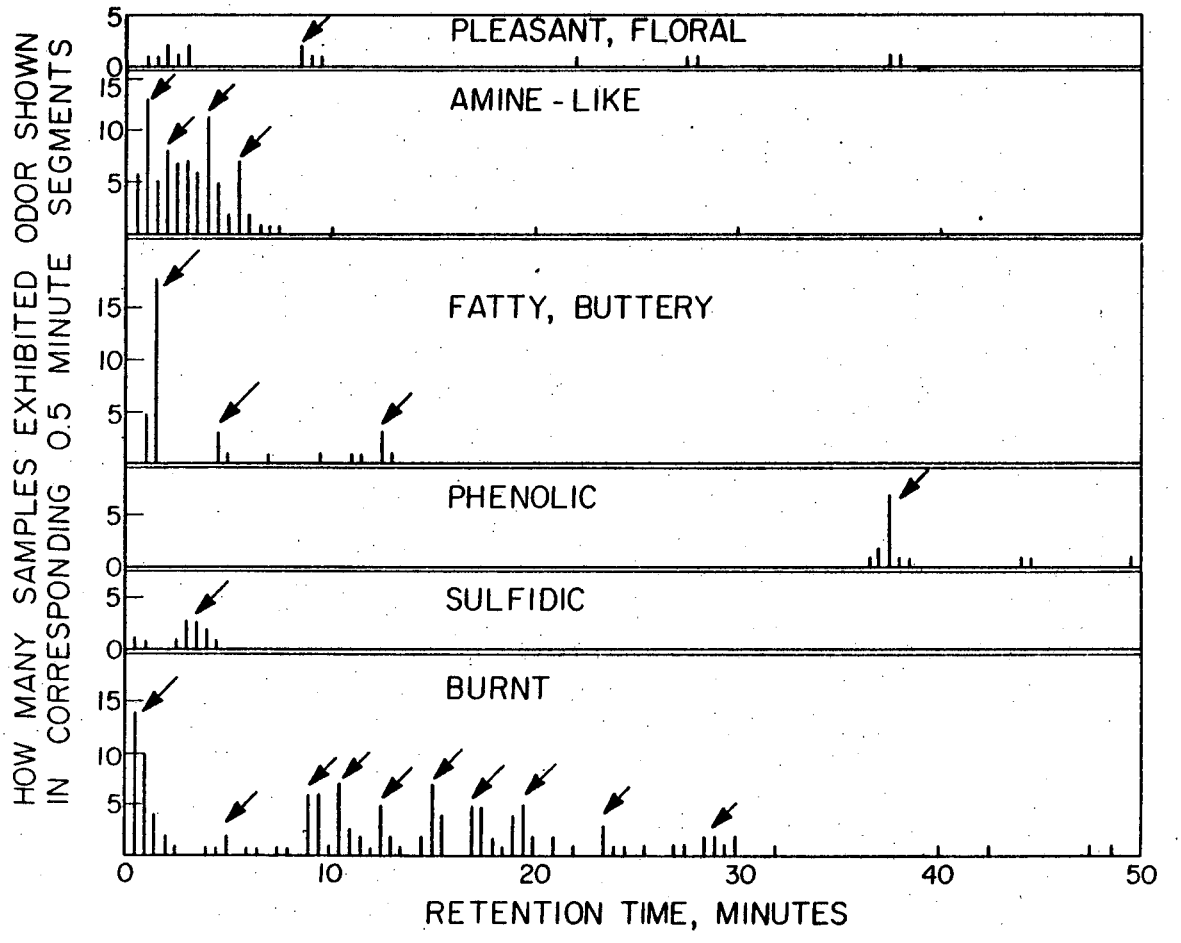

Figure 39. Composite odorogram for tobacco smoke odors.

Some problems may originate inthe odor control process. An active carbon bed may not be thick enough or the rate of flow through the carbon bed is too fast, and you may actually generate some odors in the bed. Some compounds get catalytically oxidized on a carbon. In restoring carbon by activation we may produce a higher level of odors. The odorogram permits a look at just what's going on. It doesn't give you any insight of what is common.

I want to make some comments on perspiration odors. There are two types of perspiration glands: endocrine glands and apocrine glands. One type generates sweat for cooling purposes and the other responds to stimulation by emotions. So one may perspire heavily when hot but it does not mean the odor will be strong. On the other hand excitement can produce high concentrations of apocrine perspiration and almost immediately you can have a pretty strong odor. This may be a factor in stress situations like in hospitals.

In summary, there are many things which could be pinned down to engineering dimensions and tools are available to do so. In many cases data can be obtained by the differential method where you compare two things.

Effect of Increase in Odorant Concentrations on Detectability and Intensity

Dr. Andrew Dravnieks
(Supplementary Contribution)

The following estimates are developed for two levels of odorant concentration increase. A concentration level existing at ventilation rates of 20 CFM is taken as the base. Twofold and fourfold concentrations are assumed to result from a decrease in the ventilation rates to 10 CFM and 5 CFM, respectively.

Odor Detectability

Odor detectability is related to the odor threshold which is defined as the odorant concentration (or that dilution of odorous air) at which odor can be detected at some statistically appropriate, significant level. Usually, threshold refers to the concentration that odor can be detected in 50 percent of trials. More elaborate statistical definitions also have been used.

Individuals differ in their ability to detect odors. The distribution of the sensitivities tends to follow normal (Gaussian) statistical distribution curves if the concentration, or dilution, is expressed in logarithmic form. Hence, plots of sensitivity distribution for a larger group of normal individuals tend to be straight lines in logarithmic versus probability coordinates.

Amoore (1967) evaluated odor detection thresholds for isobutyric acid which smells rancid and fatty, and is related to the components of perspiration; his data for 88 subjects are shown in Figure 40. Wilby (1969) evaluated odor recognition thresholds of 18 sulfur compounds; his data for ethylsulfide which

which smells foul, garlicky, and ethereal are also shown in Figure 40, based on 33 subjects.

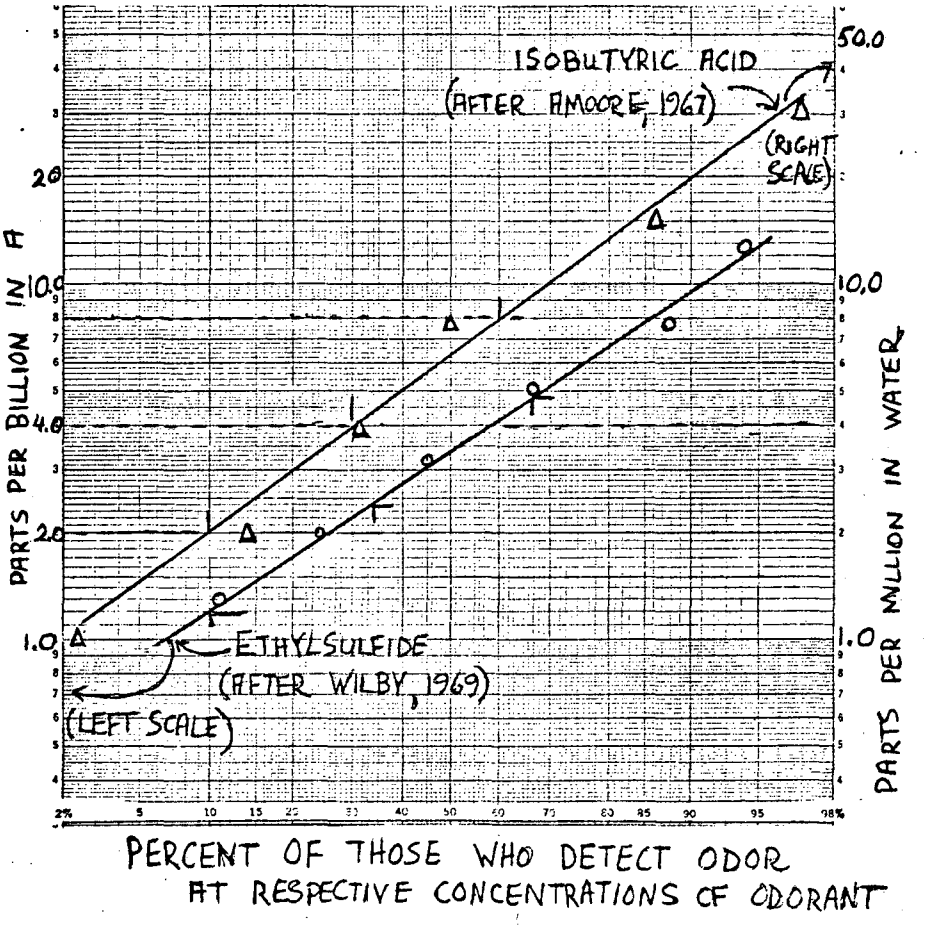

Figure 40. Effect of concentration increase on percent of individuals who would detect odor.

For an estimate of the concentration effect, assume that the concentration is low enough, so that odor is weak and only 10 percent of subjects can detect it. This would be at 2 ppb for isobutyric acid and at 1.2 ppm for ethylsulfide. The percentages in Table 33 result from doubling and quadrupling these base concentrations.

The increase in percentage of people who would begin to detect odor as the ventilation is reduced by factor of two or four is substantial. The need to reduce emissions from odor sources will increase if the ventilation rate is decreased.

Table 33

Odorant	Percent of subjects who would detect odor at: Base Concentration	Doubled Concentration	Quadrupled Concentration
Isobutyric Acid	10	30	60
Ethylsulfide	10	34	66

Odor Intensity Above Threshold

Once the odor has exceeded its threshold level, the intensity of the odor sensation does not increase proportionally to the odorant concentration. Odor intensities above thresholds can be evaluated either by magnitude estimates method or by means of a scoring (category scale) system. Extensive data exist in literature for both types of approaches.

Estimates Based on Psychophysical Power Function.

At concentrations above the threshold, the perceived intensity of odor, that is the intensity of odor sensation, usually relates to the odorant concentration through a psychophysical power function: $S = kC^n$. Here S is the perceived intensity, with a numerical scale in which magnitudes of numbers are proportional to the intensity of the odor sensation; C is the concentration of the odorant, and k and n are coefficients. The values of n for odors are less than unity, so that an increase in the odorant concentration by a factor of 2 does not result in an odor which feels twice as strong.

Patte and others (1975) tabulated adjusted literature values of n for 110 substances. Figure 41 is a histogram of distribution of n values, which range from 0.1 to 0.9. The median value is 0.35.

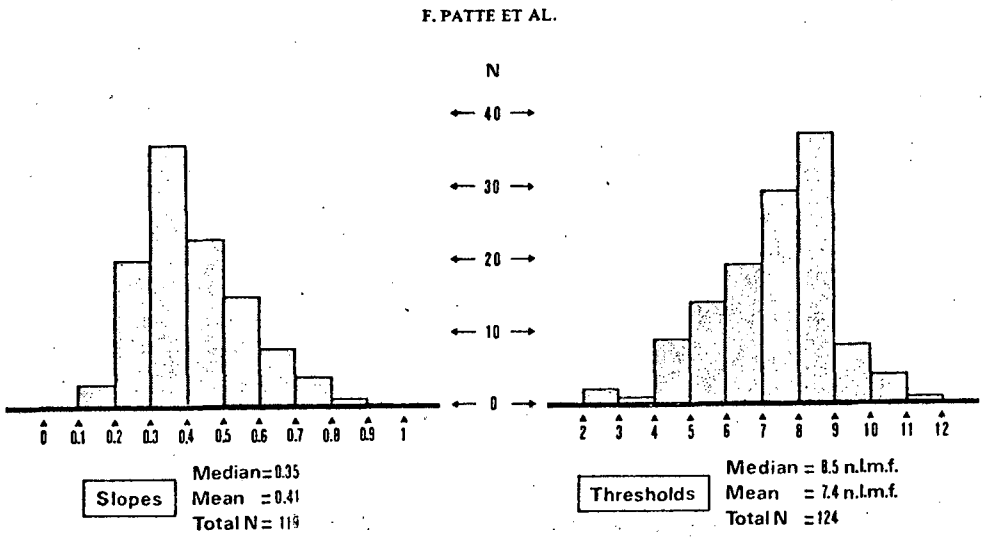

Figure 41. Distribution of standardized slopes and thresholds.

Estimates of percent increases in odor intensity if the odorant concentrations are doubled or quadrupled are given in Table 34 for three levels of n values. Standard deviations in evaluation of odor intensities by the best methods, for example, reference-odorant linked, are of order of 50 percent on the S scale. Thus, for the first line in the table, and for the doubled concentration in the second line, the intensity increase is marginal. For the other sets of condition in the table, the intensity increase will be noticeable.

Table 34. Percent increase in odor intensity of concentration.

Value of n	Percent Increase in Odor Intensity of Concentration	
	Doubled	Quadrupled
0.35	27	62
0.50	41	100
0.80 (rare	74	203

Estimates Based on Category Scale.

Katz and Talbert (1930) in their classical study on the odor intensities of warning agents scored the odor intensities of 55 strong odorants, including sulfur and nitrogen compounds, at several odorant concentrations. The score scale consisted of six categories, zero to five. Category one was defined as "very faint odor," and Category two as "faint odor."

To convert "very faint" to "faint odor," quite significant concentration increases were needed. The factors by which the concentration had to be increased to effect such an intensity increase were different for different odorants, and ranged from 3x to 71x.

Typical values of factors for some selected odorants are listed in Table 35 . Concentration increased factors to convert "faint odor" to "easily noticeable" were similar for the respective odorants.

Table 35. Factor by which the odorant concentration had to be increased to convert "very faint odor" to "faint odor."

Odorant	
Allylisothiocyante	3
Nitrobenzene	3
Allylmercaptan	3
Allylamine	5
Hydrogen sulfide	6
Crotonaldehyde	6
Pyridine	9
o-Chlorophenol	9
Skatole	12
Methylmercaptan	14
Methylsulfide	23
Ethylsulfide	25
Thiophenol	52
Allylsulfide	71

For those odorants for which the factor is four or less, odor will increase to faint from the very faint if the ventilation rate is decreased by a factor of four. Thus, with reduced ventilation, need for reducing odorous emissions from various sources in hospitals will become important. For cases where a faint odor already results, and the factor in Table 35 is large, reduction of emission must be very substantial before the odor intensity will noticeably decrease.

Summary of Effect of Decreased Ventilation on Odor

Effect of reducing the ventilation rate from 20 CFM level to 5 CFM on odor detectability may be significant for most odors, and on the odor intensity above the odor threshold significant for a substantial fraction of odors. Inventory of in-hospital odor sources and evaluations of odorous emission rates and odor dilution thresholds from such sources could provide a basis for deciding which if any odor sources need to be controlled if the ventilation rates are decreased by odors maintained at pre-existing or decreased levels.

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Aesthetic Factors: Discussion A

Dr. Martin Favero

DR. FAVERO: The panel is going to have to set some priorities. I'm always amazed in terms of standards that chemists are not too reluctant to set a standard, but microbiologists are very reluctant to come up with a standard. For instance, if you asked how many microorganisms per cubic foot of air is allowable in a hospital operating room, you would probably come up with three or four different answers from Dr. Ulrich, Professor Michaelsen and Dr. Vesley. It would take us days and perhaps weeks to reach a concensus. I believe one of the things we should keep in mind is that there are some definite criteria for setting guidelines or standards. The first would be any epidemiologic evidence that incriminates a chemical contaminant. Is there a study to support this and does it make good scientific sense? Secondly, if a guideline is set almost intuitively one almost has to have a procedure or set of procedures to qualitatively and/or quantitatively determine the chemical. Lastly, cost effectiveness is the bottom line in our considerations. Perhaps with some of these things in mind we can start the discussion of environmental contamination in hospitals -- chemical contamination.

MR. MICHAELSEN: We consider the hospitalized patient as less able to cope with his environment than normal individuals. Are there medical conditions under which you would be more concerned about certain chemical contaminants, such as carbon monoxide content? I cite carbon monoxide as an example because it is one of the outside atmospheric contaminants of concern. In the Twin City area there is a hospital close enough to the freeway that carbon monoxide from the freeway adds to the contamination problem for the fresh air supply for the building.

DR. ULRICH: One of the interesting statements made by Mr. Chatigny this morning was that 10 to 15 percent of the hemoglobin is tied up as carboxy hemoglobin.

MR. SODERGREN: In the Swedish codes we have one-tenth of the hygienic level for CO_2 for carbon dioxide.

DR. SOLBERG: The upper level?

MR. SODERGREN: I don't know the hygienic limit for CO_2 in the list for the different chemicals.

DR. ANDERSEN: Do you mean CO_2?

MR. SODERGREN: Yes.

DR. ANDERSEN: That's not in the National Ambient Air Standard, it's only CO.

MR. SODERGREN: I see. I can't tell you that limit either.

DR. ULRICH: Mr. Chatigny said levels begin to get derogatory around 1½ to 2 percent.

DR. ANDERSEN: The National Ambient Air Quality Standard for hospitals is adequate. Patients shouldn't need lower concentrations than those because the standards have been set in a way that very susceptible individuals are covered. It's very dangerous to start from TWA values which have been set for healthy population, the working population. Even if you divide by 40/168 and multiply by .5 then you are only at one-eighth of the TWA value. That means that no care is taken for the very susceptible individuals. On the first page of the introduction to the list of TWA values it is stated that a few percent of the workers will be sick even if these values are not exceeded. Therefore, the same thing will also happen in the hospital you just divide by one-eighth. So the background for using one-tenth of those values for indoor contamination is not valid for hospitals.

MR. MICHAELSEN: I'd argue whether it's even valid for the normal population. Just dividing by 10 doesn't impress me as being very well worked out.

PARTICIPANT: Sure, but it's convenient.

MR. MICHAELSEN: I'm not sure that the value is well set to start with and then we take a fraction of that value and say that's good enough for healthy people. But what d we say about the unhealthy? Getting back to the figure that Dr. Ulrich was quoting from Mr. Chatigny of about 15 percent hemoglobin, is that serious?

DR. ANDERSEN: Between 10 and 15 percent of a smoker's blood is carbon hemoglobin. At this level there is a decrease in performance that can easily be found with psychophysiological tests.

PARTICIPANT: Do you have any data on the use of air deodorizers or fresheners, not so much in terms of effectiveness, but in terms of long term physiological effects as a chemical contaminant?

DR. DRAVNIEKS: Nobody really knows. If you started conducting these tests you would probably find considerable fractional components. There are compounds of similar nature that can be found. It isn't being very responsible to release such components to the air. There also are problems with some people responding psychosomatically.

PARTICIPANT: It seems that a lot of these products on the market are being pushed by the manufacturers and are being used in many instances unwisely. If and when ventilation rates are indeed reduced this may increase the use of fresheners and deodorizers. There is a great dearth of real data on the safety of these products. Those that have been approved by governmental agencies for disinfectant use have been approved on the basis of their disinfectant effectiveness and not in terms of physiological effects of other components in these products.

DR. ULRICH: The public health officials have removed the intermittent aerosolizers from the restaurants in New Mexico.

DR. DRAVNIEKS: People keep mixing various things with tobacco smoke to see if it is decreased. The indication seems to be the decrease of the impact of odors. The safe aspect is quite another problem that really should be studied. Also, nobody knows if fresheners interfere with detecting a gas leak from a gas system. Gas is odorized to prevent dangers from gas explosion, and although dangerous leaks will be noticeable, non-dangerous leaks will not be noticeable. Manufacturers say it does not interfere with gas detection but that's kind of a blank statement without any support.

DR. ULRICH: There is a series of compounds available for home use that use formaldehyde. Essentially, it interferes with the nerve endings in the nose and actually deadens them.

DR. DRAVNIEKS: I believe the use of formaldehyde has been phased out.

DR. ULRICH: There are still products on the market. ..

DR. DRAVNIEKS: Do odor modifiers just change odor perception? It's obvious that they modify it somehow. It's probably relatively easy to select better compounds and have a very simple mixture of a well-know compound that could be just as efficient as some of these products. I wrote a paper on odor effects on human beings and asthmatic attacks. So, instead of using air fresheners as I didn't know what was in it, I took isovaleric acid as an unpleasant odor combined with a mixture of vanillin and citral. In conducting commercial freshener studies I found that the combination of isovaleric, vanillin and citral was more effective than the commercial combination.

MR. BANKS: Is it possible to make any general observation regarding odor thresholds versus threshold limit values?

DR. DRAVNIEKS: No.

MR. MICHAUD: Our common denominator again is the amount of air that we need to accomplish the safe contaminant level, the odor level and so on. In all of these studies has anybody come up with a level of clean outside air necessary to preclude some hypothetical concentration of contaminants or some hypothetical odor level? In comparing one of the Swedish standards with our standards on a patient rate, we require 20 CFM per patient, single patient room, and this standard is about 5 or 6 CFM in Sweden. Our recommendation is 5 times what they have and that means 5 times as much energy for that given room as in Sweden.

MR. CHATIGNY: Are you down to Yaglou's minimums?

MR. SODERGREN: No. So far we have only taken the first step. When it became necessary to save energy, we went down to what we thought was possible to use. I'm quite sure we haven't gone too far. There is still a big step down to Yaglou's recommendations.

MR. MICHAELSEN: Is somebody actually doing some epidemiological work to find out what kinds of concentrations of gases and solvents exist?

MR. SODERGREN: No. We also trust on Yaglou in that case. The smell is the first thing we will notice and that's still far under the volume which is our actual standard. We don't have any bad smell in our hospitals today.

MR. MICHAELSEN: But a smell is different at 6 CFM than at 20 CFM.

MR. SODERGREN: I'm not sure it is.

DR. DRAVNIEKS: The factor necessary in this equation would produce better marginal change in intensity. If you are around threshold it's no different.

DR. ULRICH: Of course, the threshold apparently changes. We have all had the experience of walking into an area with an odor for five or ten minutes and when you come back in again you pick it up. So the acuteness of our awareness varies depending on how we are exposed to the odor.

MR. MICHAUD: We have a double set of standards. We have a set of standards for the hospital and we have another set of standards for the rest of the world. Our commercial building occupancy standards are roughly 5 CFM per person. I haven't had a chance to interrelate the volume relationship of a space to the CFM per person and there is a relationship.

MR. CHATIGNY: Yes, indeed.

MR. MICHAUD: It appears to me that before we start spraying stuff into the air we should get the air stream down small enough to see because we do have to do some minimum amount.

MR. CHATIGNY: I think the sense of the conversation here is that airborne infection is not a primary mode of transmission in infection in the hospital. Dr. Favero, would you like to respond to that?

DR. FAVERO: I would agree with that but part of the rationale we go through to get to that point is that we, as microbiologists, haven't set the same kind of standards.

MR. CHATIGNY: Yes.

DR. FAVERO: So, in reference to odors, what I'm hearing is that you can cut down the ventilation rate and it may make a difference in terms of chemical contamination, but there are also some hard standards. For instance, Dr. Andersen mentioned in the United States with respect to formaldehyde, there is a standard of 1.2 milligrams per liter, and in Denmark

it's 3 milligrams per liter. Well, that's fine, but the standard may be counter productive in the sense that nobody is going to do any epidemiologic studies on it and we will have to live with that standard. How are you going to apply this standard in a hemodialysis center because formaldehyde is the disinfectant of choice used for hemodialysis systems. I'm not aware of any assay procedures for formaldehyde in intramural air but I would be willing to bet that formaldehyde levels would far exceed these standards.

MR. CHATIGNY: On a momentary basis.

DR. FAVERO: No, not in a large hemodialysis unit; some units in the United States operate 24 hours a day.

MR. CHATIGNY: Let's caution ourselves for a moment and separate ventilation from fresh air. Ventilation means air drawn from the outside and perhaps circulated; that's recirculated through a cleaning agent filter, carbon bed, or whatever, Restate the question.

DR. FAVERO: I really don't know. It's just been my subjective experience that when I go into a hemodialysis unit, I tend to get used to the formaldehyde. I don't know if I'm slowly killing myself.

DR. ULRICH: Fortunately, central units are off in another room where the ventilation may be poor. Your eyes become irritated with only two or three minutes of exposure. The aerial concentrations are high in units where formaldehyde is stored.

MR. CHATIGNY: So bacteria are not a problem but formaldehyde is?

DR. FAVERO: I'm not saying that bacteria are not a problem, but if you go through our conversations from yesterday, I think the bottom line is that airborne microorganisms invariably constitute a very small part of the profile of hospital infections during surgery. It boils down to how much do you want to spend to get rid of that small percentage.

MR. CHATIGNY: The bottom line at the moment appears to be chemical contamination of the environment in a hospital.

DR. FAVERO: That's what we are talking about. We are kind of burned because as soon as you start coming up with standards like this, the number of documents will double and triple.

MR. MICHAUD: I'm not sure that that's the case. You have identified a certain small area but why penalize the whole hospital as opposed to identifying the problem in that one area and giving it the proper ventilation. We need to identify special areas and localize the problem.

DR. SOLBERG: May I have a comment on this hemodialysis unit? We don't sterilize the equipment with formaldehyde in the hemodialysis unit. We bring it down to a central sterile supply unit where the washing and sterilization are done and we get it back sterile wrapped.

DR. ULRICH: There is a different problem in hemodialysis wards. The individual patient's console is a built in unit in the kidney ward and cannot be easily removed.

DR. FAVERO: It's that pathway through which the formaldehyde is put. You put in 40 percent formaldehyde and it's automatically diluted with water to about 1.5 to 2 percent. So it goes a long way.

PARTICIPANT Can that be isolated?

DR. FAVERO: Sure. There are a lot of things one can do.

DR. ULRICH: Not completely, because all the lines have to be flushed with formaldehyde which is exhausted into the sewage systems through a six inch air break which will allow aerosolization of formaldehyde. A console system that Dr. Solberg describes is a different kind of an operation. These units can be prepared elsewhere as for inhalation therapy equipment.

DR. SOLBERG: Exactly.

DR. ULRICH: Many of our hospitals are centralized and don't have that kind of setup.

DR. SOLBERG: We make all the solutions in the hemodialysis unit from tap water. We have the electrolytes in bags and throw the content into the equipment and add tap water.

PARTICIPANT: I have a question in connection with what was mentioned about the total amount of ventilated air as opposed to total air in the different areas of the hospital. One of the questions we have had for several years deals with literature that came out about 1969. Mass distribution techniques were looked at and this tremendous amount of air exchange that was being proposed for almost all applications where you could get into 30, 40, 50 air changes, maybe 300, 400, 500 air changes per hour. The concept was that the more maximum you have through the space, the more dilution you are going to have and the more dilution the better. In looking at the development of standards in hospitals in 1969, for instance, you were not allowed to recirculate any air, for example in the operating room. The Hill Burton requirements of 1969 allowed recirculation. You use 12 air changes total in the operating room, five of which had to be outside. Then the Health Resources Administration came out in 1974 with their new documents that allowed five changes an hour of outside air, but you had to increase the total air change to 25. I suspect that had to do with the mass dilution philosophy. In the new standard they say you can do either.

There are four populations we have to deal with in the hospital: the patient, visitors, medical staff and administrative staff. Each of these have to be treated differently relative to the duration of the exposure to either a gaseous or a particulate contamination. I have heard few comments in regards to the duration of the exposure. Relative to that would be the medical implications and oxygenic problems because of continuous exposure to some of these gases.

DR. ULRICH: The FDA is looking at some of these areas. Unfortunately, they are considering it only from the standpoint of the patient and it rather raises my ire because hospital personnel who are in the hospital constantly are not taken into the discussion.

One of the areas that I feel very strongly about is the protection of my own people in the laboratory areas. We set up adequate techniques, but also protect personnel. In the chemistry laboratories large amounts of volatiles are used. The ventilation rates are no different than a patient's room. They are less than half of what we consider proper in surgery.

MR. CHATIGNY: Local containment is almost disregarded. I would expect that if you have any toxic gases or toxicogenic viruses you would make every effort to contain and capture those at the source. This philosophy applies to our problems in the hospital and will offer us some solution. It may be that we have to put a canopy over the dialysis unit and it may be that you would have to use better capture units in your chemical laboratories. These are all possibilities and when you consider the cost of those items with the overall cost of trying to ventilate the whole business, it's certainly a more profitable exercise, not to mention the decreased risk.

DR. SOLBERG: Every effort should be made to contain and capture toxic gases, cancerogenic viruses and so on at the source of emission. This is of particular concern in laboratories. In the hospital where we are facing the problem of transmission of microorganisms it is difficult to stick to this principle except in isolation wards.

DR. ULRICH: There was considerable interest a few years back on the aerosolization of pharmaceuticals, especially antibiotics.

DR. SOLBERG: Yes.

DR. ULRICH: Research indicated enough penicillin in the air on many floors

to produce sensitivity even though the individual had never been treated with penicillin.

DR. SOLBERG: We had that problem in the antibiotic industry where penicillin resistant strains were frequently isolated from the nasal vestibules of the people working there. Do you think that is a problem in hospitals to day?

DR. ULRICH: Even as late as six or seven years ago people were concerned with it. There have been changes in the way pharmacies prepare single use items which are discarded as soon as they are used. I don't think that is the problem.

PARTICIPANT: They also use air for the people in the hospital, expecially areas like the lab, the operating room, nuclear medicine, wherever, it should be modified.

MR. MICHAELSEN: We need to refine the whole procedure. The hospital should be split into functional areas and looked at specifically.

DR. SOLBERG: We should move from area to area in the hospital and pay attention to what is most important in certain areas. That would be more appropriate instead of discussing the areas as a whole.

PARTICIPANT: It seems a lot of the ventilation requirements, have been considered in the specification type of code where a certain requirement is set forth regardless of the conditions. Maybe we should be giving more thought to establishing performance type codes.

DR. FAVERO: Good luck.

PARTICIPANT: What is being done to assure that the amount of outside air that is brought in is uniformly distributed? One of the problems we have, especially in large departments, is the problem of stratification. It seems

that if we cut down on the amount of air this problem may get more serious.

MR. MICHAUD: In reference to the figure that shows how air is distributed with arrows on the drawing, I have found it doesn't follow the arrows.

PARTICIPANT: There is a device to properly blend air called an air blender. There are several models available that do a really decent job of it.

DR. ULRICH: One of the big problems is balancing out the area. I seem to be having unusual problems with media contamination in the laboratory. We checked the amount of ventilating air and it seemed adequate. What had happened is that in the installation of a hood, an orifice cut down the flow rate to 345 CFM instead of 1,200 CFM. Balance out will vary also with outside temperature.

MR. MICHAUD: Getting back to the original question, whether 10 percent of our total circulation is outside air, or 100 percent of it, I've got the same basic problem here of distribution. It's related to the systems that we are using within a hospital. As an example, I can use a fan coil system in a patient room and I have got 300 CFM and that is capable of circulating without any outside air. I can, correspondingly, come down the corridor and put in the equivalent of what the book says of 20 CFM per person into that room. It's a simple thing to balance and get it into the space. I would just as soon dump it into the corridor because I have probably got a toilet room that's got an exhaust system. I would just as soon have it go into the corridor, contain a dual action of pressurizing the corridor for smoke and fire control and letting the stuff go into the room and out the exhaust. What can I do with that toilet exhaust, either reuse it partially, or 100 percent, or recycle it. Again, I come down to a contaminant potential. In Sweden they are allowed to recirculate part of the toilet exhaust.

MR. CHATIGNY: In some test structures they are recirculating 100 percent of toilet exhaust after carbon filtration.

MR. MICHAUD: Has anybody done a partial with any other type of contaminant control?

MR. CHATIGNY: I'm not aware of that.

DR. FAVERO: So the primary objective is odor control?

MR. CHATIGNY: I would assume so.

DR. FAVERO: So we are not talking about microbiologic control.

DR. SOLBERG: What are the ventilation rate requirements in hospital wards? I am not thinking of isolation wards and surgery units but common wards with bedrooms, corridors and restrooms.

MR. MICHAUD: 20 CFM per person or 2 air changes.

MR. SODERGREN: It's difficult to give a short answer to that for Scandinavia. As I mentioned, for hospitals we are two years late since we have the codes of 1974 for hospitals and we have new codes for other kinds of buildings. The figure we are talking about here, down to 10, is half as much CFM per person as you mentioned you have in the United States. If we are going back to the hospital code from 1974 we should have just as much air in the hospital as you have here, around 20 CFM.

Perhaps we will change the codes and not demand only outside air. Then we can recirculate air in hospitals. If you ask Swedes at the moment if you may recirculate the air in hospitals, they are saying no, but if they look carefully in the code they cannot find where it says you use only outside air.

DR. SOLBERG: How does it compare to the United States? Does that say that it is about half the requirement in the Scandinavian countries as in the United States.

MR. SODERGREN: Yes, less than half.

MR. CHATIGNY: The ASHRAE Standard 62-73 comes down to 10 cubic feet per minute per person inwards, so it's quite similar.

MR. MICHAUD: That is too high. Two air changes, that amounts to 20 CFM per person.

MR. CHATIGNY: Well, ASHRAE is half of that and that's too high?

DR. SOLBERG: And that's only based upon your formulaes and not on the studies of air contamination, odor and toxic agents? Only on those old studies?

MR. CHATIGNY: That's right.

MR. MICHAELSEN: That raises a question because when we talked about Yaglou's data, everybody kind of smiled a bit. Does that mean this panel would suggest studies to re-evaluate...

DR. SOLBERG: Exactly.

MR. MICHAELSEN: Anybody disagree with that?

MR. CHATIGNY: It needs to be more carefully phrased.

MR. MICHAELSEN: Why are you critical of Yaglou's data? Just because of the date?

PARTICIPANT: As I understand it, his research was conducted in the laboratory between 1930 and 1938. I believe the study being referred to is when he put an occupant in a small chamber and exposed that person to individual odors such as dirty socks. That data was then extrapolated to real space, like a classroom, or office space, whereas the actual research was

conducted in a very simple closet like cell.

For instance, can you take into consideration the capacitance of the air that you would have, the basic volume of the air? What about stratification? When we talk about air changes per hour are we talking about a room with an eight foot ceiling, or with a 20 foot ceiling? I think all of these factors have to be reconsidered. We can't just accept the 1936 data, which is based on a different economy than we are looking at today.

MR. MICHAELSEN: The recognition of odor is not related to economy.

PARTICIPANT: There is a possibility that it is. What we accept now as a clean environment or what we say has to be done to provide a clean environment was not even recognized at that particular time.

DR. SOLBERG: How carefully could Yaglou evaluate air contamination and the contamination with toxic agents compared to the more precise evaluation that we have today?

MR. MICHAELSEN: He didn't do it. At the same time we put the pressure on engineers.

DR. ULRICH: Other factors already mentioned are important; for example, the configuration of a room. Old operating rooms were commonly two stories to provide a heat sink because we didn't force ventilate. The dilution factor in these rooms is different. In many of the modern surgeries we have a 10 foot ceiling.

MR. MICHAELSEN: We do have air spaces which is performance.

MR. CHATIGNY: What do you mean by performance?

MR. MICHAELSEN: To produce the quality of air you say we need, we must have some ordinance per cubic foot. We can produce that, rather than

just simply saying so much air for a certain sized room, which doesn't reltate to performance at all.

MR. CHATIGNY: All right. You are going to have to give me a chemical, biological and odorous standard for these things. Dr. Dravnieks are you prepared to give us an odoriferous standard for clean air?

DR. DRAVNIEKS: There are devices to measure humidity very easily. I think maybe we need devices which measure microbial and chemical climates just as easily as you depend on your humidity. You cannot really generate any standard until you can start measuring something.

DR. SOLBERG: One can measure the number of bacteria in the air of hospitals wards. Whether it is 50 or 150 CFU per cubic foot of air does not, however, tell you so much. We should try harder to correlate air contamination with special pathogens to the infection rate, odor the patient comfort and so on.

MR. MICHAELSEN: Then you are assuming all infections that do occur come from air? I don't think we have agreement on what constitutes infection.

DR. SOLBERG: No. You are right.

Aesthetic Factors: Discussion B

PARTICIPANT: We really don't need to go back and do more bacteriological air monitoring of areas within the hospital because we did a great deal of this about 10 years ago. I doubt the shedding rates of individuals have changed or anything else. We don't need to go back and do that unless we are definitely going to change some of the ventilation patterns.

I would like to make some comments on the Hill Burton regulations. They have recently put in several energy conserving measures. They are recommending heat recovery systems if you are dumping to outside air and they have come in with several areas where you can vary the pressures from positive to negative. These are mainly storage areas, X-ray treatment rooms or the laundry. They are also recommending that load shedding systems for the electrical and ventilation systems should be considered in light of energy conservation.

Also, there was an interesting symposium, that looked at variable volumes and variable velocities in various areas of Indian Health Hospitals which would be of interest here.

DR. SOLBERG: Could you give us the main content of these proceedings? What are the recommended air changes in a common hospital ward, for example, in your recommendations?

PARTICIPANT: They are not changed from what you have -- two air changes.

DR. SOLBERG: What measurements were used to reach the level of two air changes per hour? What kind of parameters were used?

PARTICIPANT: These haven't changed for many years. They are based on studies done 10 to 15 years ago by a number of people.

DR. SOLBERG: What kind of parameters were measured? Did they include, for example, infection rates.

PARTICIPANT: Yes.

DR. SOLBERG: Should two air changes per hour be used in all wards? Is that the conclusion?

PARTICIPANT: Well, yes. Again, some of these were arbitrary decisions made by engineers and not necessarily physicians.

DR. SOLBERG: Okay. Does that hold for all kinds of patients?

PARTICIPANT: Yes.

DR. SOLBERG: So that holds both for patients with psychiatric disorders, cancer patients, burn patients, coronary insufficiency patients -- all kinds of patients?

PARTICIPANT: I don't think you will have these requirements in the general patient areas of the hospital.

DR. SOLBERG: That's what I'm aiming at.

PARTICIPANT: You are talking about a ward. Well, we have patient areas. We might have isolation rooms which these patients are in which will have a reverse isolation and a straight isolation room which can make a big difference in the type of air that's being supplied to that room.

PARTICIPANT: There are a lot of other specialized areas in the general patient areas: janitor closets, soiled workrooms, or clean workrooms. There are a lot of existing hospitals that may have adequate ventilation in terms of patient rooms, but they are deficient in terms of other small, localized areas. Maybe we don't even really know the significance of the ventilation needs for some of those. In terms of existing hospitals that

are being asked to upgrade their facilities, this gets to be a significant part of the cost.

PARTICIPANT: You are talking about the air handling system, but how often are they designed one way, installed another way and operated in a completely different way?

MR. MICHAUD: We have found that it takes about a quarter of a CFM per square foot to handle the exhaust of such areas as the janitors closets, or the toilet rooms excluding the kitchens. Anytime you can reduce the requirements, you can naturally reduce the amount of ventilation air to maintain reasonable, either small pressure, or a neutral plane in the building.

PARTICIPANT: Can we reduce the present prescribed standard of rates and if so, by how much?

MR. MICHAUD: Well, I think we can.

MR. SODERGREN: There will probably not be any objections from any side if you keep the total amount of air but reduce the outside air to one-third. Would you like to make an objection to that because of the odors or the infection risk?

DR. ULRICH: No.

DR. SOLBERG: No.

MR. SODERGREN: Using the outside air is a good idea because people are moving inside the hospital and some times there can be many in one room and another room can be empty. If you recirculate the air you use it anyhow. For the heat it's also a benefit if you can move the heat from one side of the hospital to another, from the sunny side to the other side.

PARTICIPANT: We need to distinguish between ventilation air and total supply air. When you reduce that from 15 CFM per person, cut it to one-third so that you don't go below 5 CFM per person, that's only bringing in outside air for ventilation. It doesn't have anything to do with supplying air into the space for thermal control. You can reduce the value to 15 percent of that listed if in addition to particulate control you incorporate chemical control or charcoal filtration, for instance. You can reduce the value from the recommended or minimum values listed down to 15 percent of those listed as long as you don't go below 5 CFM per person, but that's only on outside air and not the total supply air to the space.

MR. SODERGREN: But the rules you have still say that you should have two air changes per hour of outside air.

DR. SOLBERG: What would happen to the infection rate if you lowered the ventilation to one-half?

DR. ULRICH: It depends on other factors. For example, from the study we carried out we found that it was actually better to recirculate the air from the bacteriological standpoint than to bring in fresh air because the particle size, the viable particle size of outside air, is smaller than what is generated within the hospital, especially in surgeries. So it's much easier to filter out those units when you have recirculated air than bringing in the outside air.

MR. CHATIGNY: Ventilating air or recirculation air?

DR. ULRICH: We are talking about recirculation. Right?

MR. CHATIGNY: Yes. Recirculation in a surgical unit is one thing and recirculation throughout hospital wards, as implied by Mr. Sodergren, is quite another thing. We have drawn some conclusions that the air has a direct relationship to the infection rate in the ward. I don't think that we can include that at this point. I would be cautious about circulating air from one ward to another ward, or one wing of a hospital

to another to save heat or anything.

DR. ULRICH: You can handle that by proper placement of filters.

MR. CHATIGNY: Then I would echo Dick Riemensnider -- I doubt anybody has seen a filter installation in a hospital function the way it was supposed to function when it was put in.

DR. ULRICH: They have to be checked.

MR. CHATIGNY: Who is going to check them? There is no one with the salary structure capable of doing a thorough checking job in a hospital operational picture. We are forcing a solution to a difficult problem to a low level, in fact, down to one of the lowest levels of the salary structure in the hospital where we can expect the least technical assistance.

PARTICIPANT: There is a rather inexpensive process of filtering that does a 95 percent job of disinfecting from a bacteriological point of view. You can use a lithium chloride type spray, or calcium chloride type spray. This has been used in the brewery industry for years to contain and hold the spore growth in their yeast room. We have used it in one of our hospitals, and it's done a fine job. You can also use it as a heat recovery device.

DR. DEROOS: In following up on Mr. Chatigny's comment, I would refer to a comment from Mr. Sodergren. In the recirculation question, even with one of the 15 filters missing or leaking, there was a very small percentage of change in terms of the quality of air. In other words, poor maintenance of filters has a negligible effect on the quality of the air, is that correct?

MR. SODERGREN: As far as I can understand you can count on it. In the example that I showed yesterday, we had maybe 20 cells of filters and the maintenance personnel forgot to put in one of them so the air was just passing through. Let's say that 10 percent of the air was passing through because of the lower air pressure in the empty square. If you have 10 percent

of the recirculating air passing beside the filter it means that you need only 5 percent more air to compensate the concentration of particles in the room air.

DR. SOLBERG: I haven't gotten an answer to my question. What will happen to the microbial air contamination and hospital infection rate if the ventilation rate is reduced by say 50 percent? Mr. Riemensnider?

PARTICIPANT: I don't think anybody knows. But in looking at the infection rates we have, few are airborne. Our biggest problem is getting lawyers out of practicing medicine and getting physicians practicing medicine. We might have to have a few techniques changed in patient care practices to compensate for the reduction of air.

DR. ULRICH: We have to think of the kind of infections in our hospitals at the present time in the United States. Our big problem is gram negative organisms which are not normally airborne. Other parameters that should be considered include the activities, the number of people in a unit and the degree of activity because this all relates to shedding. There are some areas of hospitals where things are fairly quiescent and still others where things are hectic a good share of the time For example, you take an area like a newborn intensive care unit where they go 24 hours a day full speed all the time. During night hours in some medical wards the degree of activity is very low. Maybe we should change ventilation rates on the basis of high activity and low activity.

DR. SOLBERG: Maybe we should increase the ventilation rate in critical areas and slow it down in noncritical areas. That's one of the most important questions we have to settle here.

DR. FAVERO: I don't think anybody would argue the point of your original question, that if you do reduce in a general ward the ventilation by one-third or one-half that you would get an increase in the infection rate. Let's say there would be a slight increase in the infection rate.

Even with a good epidemiological surveillance system you would never detect it.

DR. SOLBERG: Exactly. I agree with you because that might only represent a very small fraction of the total hospital infection rate.

DR. ULRICH: One of the biggest problems relates to procedures, the kind of equipment used. For example, inhalation therapy within the last 15 years has increased to the point where it's commonly used. If not properly taken care of, that equipment is a high source of contamination. Also, much of the newer equipment such as fiber optic proctoscopes, can be a very severe source of infection. Looking at infection rate in relation to air alone is not completely meaningful because much of it relates to other equipment that we are not going to control by recirculation of air.

DR. SOLBERG: We are totally in agreement. So in my opinion from an infectious disease point of view, the ventilation rate can be reduced the ward.

DR. ULRICH: I agree.

DR. DRAVNIEKS: As far as the odorous contaminants, it seems to me that the simplest system is to provide each room with a separate active carbon filter. Such units cost between $50 and $70. In the corner of the room, it recirculates the air at about 50 or 100 CFM for a 500 cubic foot room. That's about six air changes an hour. The circulation took care of the heavier organic materials. There is no travel through all kinds of ducts, no cross mixing so you removed odors from the source and then you can supply fresh air.

PARTICIPANT: That would cost about $18 million to buy those units. Is that a way to go when we are looking at cost containment?

DR. DRAVNIEKS: It will reduce the use of outside air.

DR. ULRICH: It is not needed in every room. With cancer patients who are sometimes quite malodorous a unit could be put into use. In a regular recovery ward the need is reduced.

DR. FAVERO: Given a hospital room where odor is not a problem, if you do what you suggest in terms of reducing the ventilation by 50 percent based on that data there would be no effect on odors.

DR. DRAVNIEKS: I don't quite understand.

DR. FAVERO: Given a hospital room, with full ventilation rates where there is no problem pertaining to unpleasant odors and then we reduce the ventilation rate by 50 percent, I assume a problem would not be created in terms of odor.

DR. DRAVNIEKS: If it's a pre-existing problem...

DR. FAVERO: If it is a pre-existing problem, that's due to other things, right?

DR. DRAVNIEKS: Selective application is the most practical way instead of building everything into a building with ducts.

PARTICIPANT: I would like to go back to the filter issue. Mr. Sodergren, in your presentation where you showed the decrease in efficiency, I assume from the model that we are dealing with a weight type analysis of the particulates so that we would have a weight efficiency. If we are talking about the potential for infection then all we have to deal with is a number efficiency, or at least an area weighted efficiency and not a weight weighted efficiency on the filter. There are three kinds of efficiencies you need to discuss and the number efficiency is what we typically deal with regarding a HEPA filter, the high efficiency particulate air filter.

Unfortunately, the number goes up inversely with the weight. With potential for infection we deal with small particles weight-wise, but a large number of those small particles. When we discuss the use of filters, for instance, in recirculation of air, we ought to be careful about the kind of filter that we specify and make sure we are dealing with either a number of an area and not a weight efficiency.

MR. SODERGREN: Particles are not particularly small. You are talking about particles of about 10 microns, maybe bigger.

DR. ULRICH: The particle size we are talking about relates largely to skin scales and Dr. Solberg talked about that in his discussion. Most of those particles are from 10 to 30 microns.

PARTICIPANT: That particle is not going to get back to your filter. It's going to drop out or settle.

DR. ULRICH: It depends upon the area that we are talking about and the rate of exchange. In a surgical area where your rates are higher you will sweep them out. In a ward area they will probably clunk on the floor.

PARTICIPANT: The point still needs to be made that the larger particle is going to tend to settle and not get back to the filter. That's why we have to deal with the number type efficiency and not the weight type of efficiency.

DR. ULRICH: You also need to think of the configuration of the particle. These things aren't spheres. They are flat plates and as a result they are more easily swept up and carried out in the air conditioning system.

MR. CHATIGNY: Aerodynamically they are about five microns.

DR. ULRICH: That's right.

PARTICIPANT: One definition developed a couple of years ago by the American College of Surgeons is a description of surgical microbiological clean air. There are three categories. One category allows one bacteria particle per cubic foot of air and the maximum number of particles in the total sample cannot exceed 30. Then you have a Class 5, which allows five particles per cubic foot. Class 20 allows 20 particles per cubic foot.

Along the same line, three definitions of operating rooms have been defined: normal, superaseptic room and ultra-aseptic room.

DR. FAVERO: What are the maximum limits?

PARTICIPANT: Class 5 is 30 and Class 20 is 10.

DR. FAVERO: Class 20 is 10? That means 20 organisms per cubic foot of air with a maximum of 10?

PARTICIPANT: No, it's the maximum by total sample.

DR. FAVERO: Just hearing it for the first time it seems to be a very confusing standard. What kind of sample would you be using?

DR. ULRICH: That must be done over a certain period of time because it relates largely to the degree of shedding which in turn relates to the activity and the number of people in the operating room. These things aren't fixed by any means. It's strictly a dynamic system and the standards indicate a static situation. What time are you going to sample? Are you going to do it right after the incision or are you going to do it when they are preparing the patient and the bacterial population is very high?

PARTICIPANT: It's defined in the publication. I'm sorry I said maximum number of particles. In the listing it's the minimum cubic feet of air that can be sampled.

DR. ULRICH: Yes, but at what time?

PARTICIPANT: During surgery. It has to be done during normal practice.

DR. ULRICH: You have to bring a patient in, prep and rape him, during which time the bacterial population is an order or two of magnitude greater than after the team settles down around the operating table.

PARTICIPANT: To backup, my comment involves the charcoal filters. A charcoal filter takes extra energy through its resistance; secondly, it's a maintenance item because that filter is no better that the maintenance it gets.

DR. DRAVNIEKS: I'm not sure moving 50 CFM can be done much more efficiently when there are no passages in or out. Regarding maintenance, are outside organizations that monitor and schedule such things.

MR. CHATIGNY: This brings up the use of multi small air handlers in individual spaces and a maintenance problem. It has also brought in some infection problems because these things become reservoirs for various kinds of bacteria.

DR. FAVERO: It's primarily in liquid systems.

MR. CHATIGNY: Yes, but if we bring in an air conditioner and we have a wet placement in one of our cooling coils which will give us a humidity condition we have a maintenance problem. We have a distributed equipment problem and usually that kind of equipment has a fairly short life. Also, there is a noise problem.

PARTICIPANT: We have talked about source control and this is certainly a preferable solution. Maintenance in a hospital is not that great. We have to face the reality that hospitals operate under strict budgets and every time there is a cutback, you know where the cuts are made. We have to balance source control and handling of problems locally versus the benefits of

overall kind of mechanical systems that may be more expensive, but in the real world better.

DR. DRAVNIEKS: Another possibility is if hospitals have oxygen distribution systems throughout why couldn't there be two systems, one for ventilation and another for taking care of those rooms which have chemical and other contamination problems and are part of the ventilation systems that could be closed with no particular demand or contaminant control.

PARTICIPANT: That's fine if we are talking about a new design, but again, let's face the fact that for the most part new hospitals are going to be a rarity. We are talking about places that are in existence.

DR. SOLBERG: I wish you could finish the filter discussion and recirculation.

PARTICIPANT: Did you get your question answered about filters and operation by maintenance people?

MR. CHATIGNY: I don't believe so. I'm still with doubt that the quality filter like a 60 percent DOP test type filter which, if I test, might be a 90 or 95 percent kind of a filter, will get adequate maintenace in hospitals.

PARTICIPANT: What do you mean by adequate maintenance?

MR. CHATIGNY: Installation, placement into the rack and adequate testing.

PARTICIPANT: From my own experience, some of those bag filters have presented problems and we have had to come up with some additional designs, but otherwise they do collapse when you shut down certain fan systems. As a basic rule I would say that hospitals are upgrading their engineering department. Once in awhile those filters roll up and there is nothing there, but again those are your low efficiency filters for patient rooms.

MR. CHATIGNY: One of our problems is really upgrading or education.

MR. BANKS: Is there a comparable problem in the Northern European countries with maintenance?

DR. HAMBRAEUS: There was an investigation about 10 years ago in the hospitals in Stockholm which showed that the majority of the filters were wrongly installed.

PARTICIPANT: Were they corrected afterwards?

DR. HAMBRAEUS: Yes.

PARTICIPANT: When the contractors install them they are not always right.

DR. ULRICH: I would like to rephrase that, they are seldom right. Another measure of control in many of the hospitals in the United States is the presence of a hospital epidemiologist who will pick up problems that relate to equipment.

MR. CHATIGNY: Sometimes, he is late -- after an overt case has happened.

DR. ULRICH: Very commonly that is true. It may be after the fact, but it is important that it be noted to contol extension of hospital epidemics.

DR. FAVERO: I would like to remind you of some of the work that has been done in the area of spacecraft sterilization. This is not done in a hospital operating room, but in industrial cleaning rooms. If you recall the work done by the University of Minnesota, the Jet Propulsion Laboratory and ourselves at CDC when we would sample an area, the type of filter on the supply air -- I'm talking about a conventional industrial cleaner room had very little effect on the microbiologic quality of the air in the room. Rather, the number of people, what they were doing, and how they were clothed had the most significant effect on the level of airborne bacteria. In some of the rooms, the actual supply air was going through HEPA filters,

but the types of personnel activities negated that very high limit of microbial contamination -- much higher than what you are talking about in those standards. The tightness on personnel control did effect reductions in levels of microbial contamination. An exception would be the true laminar flow room.

MR. CHATIGNY: The discussion stems from the fact that we are not just talking about filtering a single room, but filtering the air into a whole wing or ward of a hospital where we may not be able to tolerate, cross contamination or discross movement of particulates.

PARTICIPANT: Going back for a minute to what Ed Howard said about our hospitals, we have got 7,200 hospitals and 50 percent of them have about 20 percent of our beds. The average size hospital in the United States is 93 beds. I also think that hospital engineers have upgraded their profession. We should also remember that we are looking at cost containment in hospitals.

DR. DEROOS: Backing up again, the quality of the air in these rooms was not greatly effected by a leak in the filter or a faulty filter, but it was more effected by what was going on in the room. It seems to me that, we can recirculate a lot of air even if the filters aren't properly maintained, it won't make much difference. Is that correct, or don't we know?

DR. ULRICH: Generally, that's correct. What goes on in the room, is more important than the filter.

MR. CHATIGNY: Do you really want the staff of the hospital exposed to air of the infectious disease ward without proper filtration?

DR. ULRICH: We do separate people into certain areas. We need to do more of that and we have to design a system to take care of it. For example, a newborn intensive care unit is an entirely different operation

than a post-surgical area. The maintenace of temperature, humidity and light in these areas is far more critical than in the average ward. We ought to stop thinking of a hospital as a homogeneous glob. It consists of all sorts of fractions and we have to pay more attention to what these fractions are.

Another area mentioned is noise pollution in relation to air handling. This has become critical in some areas, especially in the laminar flow operating rooms. They are very noisy because of the amount of air that is recirculated through them. The greater amount of air you push through filters the greater amount of heat produced and thus, the greater the noise level. Many of us have learned to get along quite well with low frequencies.

MR. MICHAUD: I am very concerned about what we are doing in Rochester where we have the major mechanical room directly above surgery and it's a low frequency sound. I am also concerned about the vibrations.

MR. CHATIGNY: Regardless of treatment, can you get the sound in a laminar flow room with say 80 or 100 feet a minute downward or horizontal velocity much below 50 or 60 DB?

MR. MICHAUD: I hope so.

MR. CHATIGNY: That's quite an accomplishment. But really the sound is being generated right at the orifices that the air comes out of in the plenum.

DR. FAVERO: Yes, a lot of the noise has to do with the air moving.

MR. CHATIGNY: ...the air flow, the movement as it come out of the holes.

MR. MICHAUD: A lot is generated right at the fan and that's the low frequency.

DR. ULRICH: Generally speaking, personnel working in operating rooms are less sensitive to low frequencies than they are to high frequency. Equipment that produces low frequency sound causes little reaction, but when equipment produces high frequency sound the surgeon must be warned beforehand. If not warned, he might react at a critical time.

With increased air flow the frequency of sound increases but these waves can be trapped more readily than the low frequencies.

DR. FAVERO: Of course you are talking in terms of a hospital worker. Anybody who has been a patient in a hospital would notice this. I don't think one would notice it until it was pointed out. Hospitals are notoriously noisy: vacuum cleaners at 5:30 in the morning, bells ringing for communion at 6:00.

PARTICIPANT: Along with the problem of sound with recirculation of air, I would like to hear some comments on pressurization control. One of the major problems that concerns me is how do you measure or confirm that you have certain pressure relationships? I have a strong feeling that it is never done because we don't know how to do it. If we are going to have zone control we ought to enforce it otherwise we ought to say it's no problem.

DR. ULRICH: You don't have control. I have watched many times when the operating room door is opened. Immediately, the pressure differential is gone. One aspect that is far more important than pressure differential is temperature differential between rooms. It is common to have a prep room where temperature is high next to surgery. Dust from the surgeon's gloves comes in the door and up over the operating table. This was due to temperature differential. We have given a lot of time and effort to pressure differentials which disappear as soon as you open a door. With the door closed, differential is re-established

MR. MICHAUD: As I recall we had a sliding, automatic door between the prep room and the operating room and we had some very elaborate control

systems to try to maintain that differential pressure. It took about two months before it was abandoned. It just didn't work and we did not have a pumping action.

MR. CHATIGNY: Dr. Lidwell has done some work on that and I think Dr. Hambraeus also has done some work.

DR. HAMBRAEUS: Not on temperature.

DR. SOLBERG: From a microbiological and infectious disease point of view, I don't think I would mind if you reduced the ventilation rate by 50 percent, for example.

MR. BANKS: When you say 50 percent, do you mean 50 percent of the ventilation air or 50 percent of outside air?

DR. SOLBERG: Outside air.

MR. BANKS: 50 percent of what? What base? The current Hill Burton standard?

DR. SOLBERG: Yes, of what you use in the United States, not what we use in the Scandinavian countries.

MR. BANKS: Why don't we go to the Scandinavian standards?

MR. CHATIGNY: Why don't we go to the ASHRAE standards?

MR. BANKS: What you are saying is that we should use ASHRAE 62-73 type standards except for certain special cases?

DR. SOLBERG: Yes.

MR. CHATIGNY: I would like to respond to Jim Wood's question. If you

are attempting to maintain a differential pressure to establish a directional flow and if you are trying to establish a directional flow, then the basic system must have a flow capacity to establish and maintain it under all conditions, hopefully with the door ppen. So if I want a room under a positive pressure, leave both doors open and there would be enough air coming in so it goes out at a sufficient velocity to overcome the thermal head, and to overcome the inflow. That's an almost impossible situation, but idealized in a laboratory. It is a reasonable philosophy and effects the selection of the type of fan used and the sizes of the fan and duct work and filters. It's a mechanical engineering problem.

PARTICIPANT: In designing the hospital, we should have zones within zones of pressure control. We don't address this and I think in the total environmental control in the hospital, we need this.

PARTICIPANT: Would we be referring to Table 3 of Hill Burton and go through everyone of those items and reduce those ventilation rates? Patient rooms show minimum outside air changes of 100 percent outside air. We go by the minimum so we cut it by 50 percent -- was it outside air?

MR. SODERGREN: A third outside air.

PARTICIPANT: A third then and the rest recirculated?

MR. SODERGREN: Right.

PARTICIPANT: Here we have got 100 percent if you went just by minimums. Everything is listed here and even looking at a janitors closet, you have 10 total air changes for the janitors closet and quite a variation. Do you immunize each one and come down with a percentage of outside air versus total air. It's going to be a long study, but that's going to have to be the approach to take. The same thing with positive, equal or negative pressure from the room to the corridor. The patient room was positive, and the patient room corridor is equal. Isn't that in violation of fire codes now, right?

MR. MICHAUD: In some cases.

PARTICIPANT: Yes, because of smoke control -- fire control.

DR. DEROOS: One of the things we have to be cognizant of is what are the most significant changes in terms of energy conservation. I believe that because of the numbers of patient rooms and corridors that we should focus some attention on that area.

PARTICIPANT: The crux of the problem is changes to existing buildings. New designs are important, but they are very few in number and if we are talking about existing buildings, the costs aren't the same as when you are talking about new buildings.

DR. DEROOS: Maybe Mr. Michaud could comment on the significance of lowering air volumes in existing buildings.

MR. MICHAUD: One of the important things to do is to get an audit of various buildings because there are a number of systems in them. What I can do in one building, I can't do in another building.

PARTICIPANT: I would like to comment on the dicotomy between a descriptive standard and a performance standard. When we deal with the HRA is a proscriptive standard and that means if we are going to comply with the standard we have to meet that specific incident. The real battle is to be able to establish what Dr. Solberg was getting at earlier, that is what is necessary to minimize infection and to minimize complaints due to odor or thermal conditions, and so on. Once the space is defined, then establish some guidelines. But that's pretty well dictated by the existing systems and also by the creativity of the people working in the area. I would hope that if any standards are proposed that it's with regard to the occupants of the space and not necessarily the CFM per person, or air changes per hour, or anything that would be proscriptive.

DR. ULRICH: This should be done on a reasonable basis because on a nursing ward, hospital infections are not usually airborne infections, they are related to direct contact between patient and hospital personnel. In surgical suites where barrier technics are practiced this probably isn't true. Airborne infections are more important in those areas and also in areas with compromised patients and high risk areas.

PARTICIPANT: Could you define that as being an acceptable air quality within that space?

DR. ULRICH: That's right, you can.

DR. DEROOS: You can define the kind of occupancy you have in the space, but the brick wall that we run up against is numbers of organisms. When you get down to the performance standard for that, the numbers of organisms...

DR. FAVERO: The standard you mentioned -- you could get 10 environmental microbiologists and they would talk for a whole week and not get a concensus. We tried to apply the same kind of thing in industrial clean rooms and in spacecraft assembly areas and it just didn't work. We had to go to an entirely different system and that was using airborne collecting surfaces. That is not the type of data he is talking about where you would use a slit sampler.

PARTICIPANT: That's proscriptive in that it says if you are going to apply it then you have to have this -- you have to come within this quantity. Performance is probably going to be dictated by the medical staff, too.

MR. BANKS: What would you call a performance standard, if that isn't?

PARTICIPANT: It becomes somewhat of an ethical issue but whatit is acceptable level of infection that you know we can live with, or a level of chemical contaminants and various other parameters that you want to establish.

This is where we want to go, but I don't think we are ever going to get there. We have to look toward performance standards, but recognize the fact that we are going to be working really with specification standards.

PARTICIPANT: We need another approach. We have to get together with that patient care team and ask what basic practices can be changed to take care of a patient in an environment that we might change slightly by ventilation patterns. There could be a lot of things in patient care that could be changed. Florence Nightingale started doing certain things in her hospital and they are still being carried on. In discussing this with a patient care team, we could come up with some things that could change in patient care practices that we could reduce, certainly things within the environment,energy-wise to benefit us all.

MR. BANKS: You have made a good point. We have become quite aware that while realistically the focus of this project is on heating, ventilating and air conditioning, to do this job in a responsible sense we will have to look at all things that make a hospital unique from other types of buildings.

MR. SODERGREN: Can we go into the question of recirculation? Do you think it will be the odors which will decide how much we can recirculate? Isn't that so the molecules of odors will breakdown after a little while so if you give them time they disappear and don't notice the smell anymore? Are the thresholds of the kind of odors we have in hospitals high or low?

DR. DRAVNIEKS: Very few molecules will break down by themselves. They will disappear either through venting out or absorption of walls and other equipment gradually. There are quite a number of thresholds; for instance, perspiration odor,isolitic acid, which have other thresholds. Foods contain materials which have extremely low thresholds. Molecules which appear in hospitals cover a broad range of thresholds with many having quite low thresholds. Absorption is the only effect other than ventilation which will take care of the molecules. The concentrations are so low for each one

that the probability to reaction with any other kind of molecule is quite low.

DR. HAMBRAEUS: I would like to refer to an article by Lidwell in which he shows that it's possible to calculate the air exchange through doorways and what effect temperature, turbulence and ventilation have on the air volumes that are transfered. It would be possible to calculate the level of airborne contamination in a room if you know the ventilation, the activity in the room and so on. I think that when designing ventilation systems theoretical calculations are used more often in order to estimate the effect on temperature and humidity than on bacterial contamination. But there seems to be possibilities to use theoretical calculations also for bacteriological purposes.

PARTICIPANT: What I would do would be to throw it back to the engineers and say you give me the figures and we will check them but then he is going to complain because he doesn't have that kind of time.

PARTICIPANT: I have a question. Along the lines of performance standards since we have been wrestling with this because we are in a position now that we are going to review standard 62. If it goes to the area of performance so that we can define indoor air quality for different areas it is going to have to be a series of steps that we go through to have and I'm not sure that anybody is ready for them yet. First of all, we defined acceptable criteria which is going to be very difficult in itself. Once we define the criteria how do you measure the variable, the sensitive variable? Once you have measured it, how do you control it? The control sensors that would be used for real time feedback control are going to be different than what we do as far as measurement analysis is concerned. What kind of control systems are going to be available? How do you enforce a performance type criteria? Each of those points will have to be weighed carefully.

MR. BANKS: Are we talking about a fairly major revision to 62 over the next five years? What's your best guess as to how it should go in the area of performance standards?

PARTICIPANT: I don't think I could guess. We are going to work on a one-year timetable for 62, which would bring it into conformance. Beyond that point it's going to be a simultaneous development.

MR. CHATIGNY: One of the things we are all looking at with anticipation is enthalpy control, both from the inside point of view and the outside point of view. Do you see any application of this in hospital ventilation? Enthalpy control as far as the inside is essentially an option, or whatever, and we talked about not ventilating rooms that aren't used -- spaces that aren't used.

MR. BANKS: When you talk about enthalpy control are you really talking about the percentage of outside versus recirculated air?

MR. CHATIGNY: No, both inside and outside. This is making optimal use of the outside air and further matching the occupancy needs inside to the air.

PARTICIPANT: Biofeedback type of mechanisms can be used so that you are able to recognize the occupancy level based upon enthalpy of that indoor environment. This goes back to the concept of the relatively insensitive effect that we perceive in the change in relative humidity in an occupied space. It's much less a factor as far as our subjective response than temperature is so we let the humidity float and by staying within the other criteria such as contamination criteria or odor criteria, then you can measure the change as a function of the occupancy load. This is a good possibility. So far we have talked about minimizing outside air for energy conservation.

The other side of the coin also has to be looked at and that is when can we bring outside air in to reduce energy consumption? During the moderating periods of the year many times you can cool an occupied space by outside air and not bring on your refrigeration. Therefore, I become somewhat concerned about hearing people say they are going to go to a minimum

ventilation rate without qualification. Both of those issues have to be addressed simultaneously.

MR. MICHAUD: You are dealing with the minimum rate. If you have the permission to use enthalpy control or to use recirculated cycle --

PARTICIPANT: That's right.

MR. MICHAUD: That's the key to it.

MR. CHATIGNY: Yes, indeed. I just wanted to try that out for size here because it certainly is the drift of where we are headed and without major changes in systems which would cost us something like a billion dollars.

PARTICIPANT: We fould it very difficult to keep enthalpy controllers in calibration, even on the same building. I don't think the state of the art, in my estimation, is that far along. It's worth the money that it takes to put them in.

MR. CHATIGNY: Are you talking about latent heat detectors or other kinds of devices?

PARTICIPANT: We have buildings in which they vary from one section of the building to another. With the same outdoor air and the same indoor air and they are the best we can buy at this time.

MR. CHATIGNY: Mr. Sodergren, have you had any experience with those in your country?

MR. SODERGREN: No.

PARTICIPANT: What problems have you had, because we have had some good results, you know, like eight months payback on the cost of the items in energy savings?

PARTICIPANT: Can you achieve the same thing with just a dry bulb?

PARTICIPANT: It should be dry bulb anyway, and whether it's your most optimal conditions...

MR. CHATIGNY: Do you mean specifically a wet bulb and dry bulb?

PARTICIPANT: Yes. Set them at whichever occurs first and then switch over before you go to mechanical cooling.

MR. CHATIGNY: The details of instrumentation are critical in that particular application.

PARTICIPANT: There is an obvious point that hasn't been made. The Hill Burton standards talk about certain ventilation rates with no hint whether this has to be on a continual or intermittent basis. Take the kitchen, for example, with 10 air changes per hour. There is no need to operate those fans during certain hours. There can be a substantial energy savings when this kind of system can be shut down. This may effect balancing, but this is another problem. There should be some recognition that not all ventilating systems need to be run on a 24 hour basis.

MR. MICHAUD: There are new standards for allowing that.

SECTION IV: FINAL DISCUSSION

Dr. John Ulrich
Department of Microbiology
Medical School
University of New Mexico
Albuquerque, New Mexico

Final Discussion

DR. ULRICH: We would like to discuss areas of where trade offs can be made. In operating rooms there are techniques that can be used to cut down microbial shedding. There is considerable literature in this particular field. The ideal barriers or conditions have not been attained. Many types of gowning and suiting are quite undesirable from the standpoint of confinement of the surgical team. Many of the surgical teams make use of head hoods of one sort or another, some of which are large and cumbersome, but effective bacteriologically. Heating has been a problem in many of these suits. Personnel are entirely enclosed in plastic and the removal of perspiration and heat is of prime importance.

Another problem is that most of the suits are individually exhausted and this restricts the movement of the surgeon. Engineering wise, this could be solved by an overhead system.

I would like to open with a discussion of the control of bacteria at the personal level. The amount of air pushed through the operating room could be greatly reduced. It could be used largely to maintain comfort levels and to remove noxious or toxic material. One of the technics where we can get a good trade off is in the use of barrier techniques. I'm sure a number of you have had experience with these technics.

MR. CHATIGNY: Before you open the floor, I would like you to respond to some work you did some years ago wherein you concluded that you needed about 20 to 25 air changes per hour for the thermal comfort of the group in the operating suite.

DR. ULRICH: In that study, the 25 changes were optimal for control of airborne bacteria. We could go as low as about 18 to 18½ changes per hour.

Mr. Michaud designed those rooms with 17½ changes to take care of the heat load. He hit it right on the head. When we used 17½ changes we got many complaints. This is another area we ought to discuss, but first, let's discuss barrier techniques.

The use of other methods to help control skin populations in operating rooms is important. Chlorhexidine is probably the best skin germicide yet developed. Not only is it rapid in its killing activity, but it gives a prolonged period of protection. This is important in other hospital units other than surgery. There are techniques for control of skin bacteriology, which control in quite a different manner than the vacuum cleaning systems in use at the present time. The amount of air circulated through the operating room can be reduced with the use of these techniques.

DR. SOLBERG: Dr. Hambraeus may comment upon the suit but I will confine myself to disinfection of the skin of the patients and surgeons.

We have used hexachlorophene disinfection of the patients' skin mainly in orthopedic surgery and particulary in hip replacement but also in other types of surgery if the *Staphylococcus aureus* infection rate is considered too high. In hip replacement, an infection may cost $50,000 to $70,000 which includes loss of income for several months and cost of hospitalization. If, therefore, the postoperative wound infection rate can be reduced from 2 or 4 percent to 0.5 or 1 percent that does not only mean less trouble to the patients but also lowered expenses.

The procedures are simple. We usually give the patients a bath (full body scrub) with a hexachlorophene disinfection the night before surgery. Special attention is paid to the axillae and perineal area. The procedure is repeated the next morning immediately before the operation. In controlled studies we have shown that this reduces the wound infection rate with *S. aureus*.

During periods with a high postoperative *S. aureus* infection rate, our

surgeons also use hexachlorophene skin disinfection regularly not only on their hands but also perineum and axillae once a day or so.

As I have shown you in experiments with patients, a heavy disperser who may disperse by the hundred thousands of *S. aureus* carrying particles per hour may be converted to a virtually nondisperser by short-term hexachlorophene skin disinfection. We have also used chlorhexidine skin disinfection which may be better than hexachlorophene disinfection since it is more effective against gram negative bacilli.

DR. ULRICH: Hexachlorophene preparations have been used in the United States for some time and we have carried out extended studies on both the rate of killing and the period of protection. Chlorhexidine is far superior to hexachlorophene in comparison of rate of killing. Hexachlorophene requires approximately 15 minutes to degerm the surface of the skin while chlorhexidine does it in one minute. Hexachlorophene has a long period of protection of approximately three hours on normal skin. Chlorhexidine has a period of protection that appears to be again as long as hexachlorophene but has the advantage of a rapid kill. It's not quite as fast as the iodophores. The idea you put forth of prepping people, including the patients,with fully body scrubs, would certainly be a means of controlling the number of viable organisms. We are not going to control shedding by antibacterials alone, but if we can destroy the organisms on the skin scales, we are less concerned with the rate of shedding. This is an area where a great deal of education must be carried out, both in nursing and in the surgical areas . The trade off in controlling the number of viable particles in the air would be long enough for the average surgical case.

DR. SOLBERG: We have also studied chlorhexidine and if you are afraid of gram negative organisms it's much better than hexachlorophene. The only drawback to us is that if you are going to use it for a total body scrub it can be a little expensive.

DR. ULRICH: We compared the cost of chlorhexidine and hexachlorophene in this country and chlorhexidine is cheaper than hexachlorophene by about two-thirds of the cost.

DR. SOLBERG: It's vice versa in our country.

DR. ULRICH: Within the next year and a half the patent rights run out on chlorhexidine and the price will drop.

Dr. Hambraeus, would you like to say something about barrier techniques?

DR. HAMBRAEUS: Concerning protective clothing for the surgeon at an operation, there are two different problems: 1) to prevent shedding from the surgeon, and 2) to prevent transfer of the bacteria that the surgeon has contaminated his clothes with during the day. We have been more concerned about the bacteria that you pick up from patients with infections as these may be more pathogenic than with the bacteria that you actually shed yourself. Also it is only 10 percent or less of the male population and 1 percent of the female population that disperse *Staphylococcus aureus*.

We have quite clear evidence that there is a magnificent pickup of bacteria during the day when you are tending to patients. So one fairly easy thing to do would be to stress that the surgeons should wear clean clothes underneath protective gowns.

With regard to protective gowns and shedding of your own bacteria, that is another much more difficult problem. It has been shown in a lot of studies that you disperse more bacteria with the more layers of clothes you put on due to friction between skin and clothing and layers of clothing. It has been claimed that nurses should have pantyhose in operating wards but it has been shown that they actually shed more skin scales in that case than if they have no stockings. Several studies concerning the common cotton protective gown show that they reduce the dispersal from the surgeon very little, or not at all. To really reduce

the dispersal from the surgeon you have a dress made from material or plastic. Then you need an exhaust system because this would be too hot to work in. For the moment, plastic-laminated paper gowns or ventile gowns are best, but still they are not 100 percent bacteria barriers. These gowns should reduce the shedding from the surgeon himself by about one-fifth in a condition where you have some kind of air flow going down just over the surgeon himself, otherwise you will have the turbulent airflow coming up again.

DR. ULRICH: Materials for the perfect barriers are lightweight plastics. The pore size is much smaller than the size of bacteria, but the paramount problems are the removal of humidity and body heat. I do not envision a great problem here because air could be released around the foot and wrist and exhausted in the region of the neck. Present systems ventilate only at the head and the neck areas.

I can envision lightweight sterile plastic suits as the only garment worn which would dispense with the many layers of gowning now used. The problem of increased layers adding to increased shedding would be lessened. It has been shown that visible perspiration relates to an increased number of organisms on the surface of the skin and to increased shedding. New barriers that have a random laydown of fibers are also plasticized and are superior but are far from a perfect barrier.

A number of surgical groups are using barrier techniques based largely on the methods introduced by Charnley in England. Other than some varied arrangements of head gear, they have all followed the same pattern.

DR. HAMBRAEUS: The reason for the difficulty in finding good bacteria barrier material for clothes is that you can't measure the pore size alone. There is not a very good correlation between the bacterial barrier effect and the filter effect on airborne particles when these are sucked through the material. In use you have a certain amount of friction and it seems as if the bacteria by friction move through the pores, so these need to be

even smaller than you would imagine. Then you have a further transfer through moisture. So you have to have a much smaller pore size than you would think considering the size of the skin scales. Also, you must have material that is water repellant.

DR. ULRICH: The kind of barriers I envision are the barriers we use as wrapping for sterilization. They resist passage of bacteria quite successfully.

There are other technics that can cut down shedding. The English have concentrated on the perineum as a high area of shedding. The surgical team smear themselves with Vasoline, and it has effectively reduced shedding. Full body microbial sampling of human skin shows an extremely high density of bacteria on the head and the neck. Most present masks cover the nose and mouth leaving high density areas completely unprotected.

DR. HAMBRAEUS: There are investigations that show that if you wear a mask there is an increased shedding of bacteria because of friction caused by speaking.

DR. ULRICH: A study of nasal carriers showed that surgical teams having surgeons that were nasal carriers and doing the same type of surgery as other teams that didn't have carriers, had no higher infection rates.

MR. MICHAELSEN: What does this have to do with rates of ventilation in surgery, or the ventilation part of the problem?

DR. ULRICH: There are several areas we are trying to control in surgery. The first application of ventilation was removal of explosive anesthesia gases. With the advent of inductive anesthesia systems, the amount of these gases leaking in the surgical area is very small. Underwriters no longer consider anesthesia gases as we use them today to be a danger. The second need for ventilation is for personal comfort factors. Modern operating rooms are smaller in cubage and lack the heat sink capabilities of the larger and older operating rooms. More recently, a third use of

ventilation encompassed the reduction of bacteria loading in the air. If we are not actively shedding into the air, a lower rate of exchange is possible. We have greatly increased the rate of air exchange in laminar flow systems to reduce the numbers of bacteria in the air with a greatly increased energy requirement.

Modern operating rooms have heat loads that require more than the legal minimum of 12 changes per hour and design is more for heat load than the removal of bacteria. The new, high-rate, flow-through systems have been introduced to control airborne bacteria.

MR. MICHAELSEN: That assumes that airborne bacteria have something to do with infection?

DR. ULRICH: Correct.

MR. MICHAELSEN: Does everybody agree with that?

DR. ULRICH: No, not everyone. Dr. Laufman, of Miami, argues the counter.

DR. FAVERO: Let's say you reduce the ventilation rate by one-third and just look at two things: 1) infection rate, and 2) the level of microbial contamination in the room as emanating from the surgical team. I find it hard to believe there would be any difference in infection rate or that there would really be any significant difference in the level of microbial contamination, considering that this is basically a turbulent type of room, a room that's not laminar flow. So if the ventilation rate was cut by one-third, I wouldn't think that the level of microbial contamination would be an order of magnitude.

DR. ULRICH: The Mayo Clinic study reported at a National Science Foundation symposium is a case in point. Two operating rooms were set up. One had a rate of approximately 14 changes per hour. The other one had a rate of approximately 18 changes per hour. The same procedures

were performed and the same people worked both rooms. The room with 14 changes per hour came out with a 1.3 percent infection rate. The infection rate in the room with 18 changes per hour was 0.7 percent. That's quite a change at that level because you are approaching the irreducible minimum. Actually, that's a small difference in the rates of change, only four changes per hour. The surgical teams, the types of operations and the configuration of the rooms were essentially the same. The important difference appears to be the rate of air exchange.

DR. FAVERO: Are you implying then that 0.7 percent of infections were airborne?

DR. ULRICH: No. But the difference between 1.3 percent and 0.7 percent relates to rate of exchange. Let me refer to our studies that correlate postoperative infections with the presence of heavy shedders of *Staphylococcus aureus*. We had seven episodes that all followed essentially the same pattern.

In one situation, 12 cases of infection were noted in a two-week period on the same surgical team. The same phage type of *Staphylococcus aureus* was isolated from all 12 patients. Since this organism is commonly recognized to be airborne, a shedding study was performed on the entire surgical team. One of the surgeons in training was shedding large numbers of *S. aureus* of the proper phage type. We found he had a layer of boils around the beltline but we eventually controlled his shedding with the use of an autogenous vaccine and allowed him back into the operating room. He did have the proper phage type staphylococcus on the skin but we could not demonstrate any airborne organisms by our sheddding techniques. In similar episodes, shedders appeared to be dangerous but if they carried the pathogen on the skin without shedding they were not infective.

I would like to think of the production of infections on the basis of mass action. We know a certain number of organisms are required to produce an infection. We don't know how many but probably much less than many of

the laboratory studies would indicate. It has been indicated that 1×10^5 organisms will produce lesions in animals. In the case of a human being with open tissue, we might be producing infection with less.

Other factors that are important include the patient's host defense factors. These vary greatly between individuals.

We are just beginning to get a handle on some of these factors with an understanding of the action of D cells and T lymphocytes and that the T cells are probably the first and the major cellular defense that we possess.

MR. MICHAELSEN: To get back again to the heavy infection rate, the more likely source, eventhough it was shedding, was contamination of surgeon's gowns. If we could have doubled the rate of ventilation could'nt we have...

DR. ULRICH: But he still had those organisms on the skin when we let him back in and he wasn't shedding demonstrable numbers of bacteria.

DR. FAVERO: That fact didn't have anything to do with the ventilation.

MR. MICHAELSEN: We couldn't have solved that with ventilation.

DR. ULRICH: Mechanical technics can have some effect on a biological process but they are not a complete solution. Going back again to the idea of mass action, the more pathogenic organisms in the air in an ordinary turbulent system, or probably even in the straight flow systems, the greater are the chances of introducing that organism into an operative site to produce an infection.

MR. MICHAELSEN: Can you give us an idea of the numbers you are talking about? I can see large numbers, but if we are only talking about relatively few, cutting the ventilation in half isn't going to make much difference.

DR. ULRICH: I'm not quite sure what you mean by "few."

MR. MICHAELSEN: Let's say a high concentration would be 100 organisms per cubic foot of air in surgery. If I cut that in half maybe I have accomplished more than going from 10 to 5.

DR. ULRICH: That's possible.

DR. FAVERO: My point would be if you did have 100 organisms per cubic foot of air it doesn't necessarily follow that you are going to get 200.

DR. ULRICH: There are other factors in a turbulent system beyond a certain rate of air exchange increased flow is less effective in the rate of removal of airborne bacteria.

DR. DEROOS: It seems that we need the current ventilation rates essentially for control within the surgical suite. Our discussion here regarding changes of ventilation rates in surgery is not as applicable as the discussion of changes in humidity. Two of the critical concerns regarding humidity are the issues of shedding and of electronic equipment. There are no answers to these questions today. So they should be identified as research gaps.

MR. MICHAUD: That's a good conclusion. The heat load in operating rooms demands 20 to 25 air changes per hour. The biggest component of energy now is the criteria of dry bulb temperature and relative humidity. Dr. Ulrich, in the study of orthopedic rooms, do you recall what the ceiling heights were?

DR. ULRICH: They were just slightly under 10 feet. In fact, the code was for 10 feet, so the ceilings were slightly illegal by a few inches.

Does anybody have other data concerning the importance of airborne microorganisms in surgeries? There is little data published in this area.

One of the problems is that when infection rates are reduced to 3 or 4 percent, which many people feel is acceptable, the number of cases required to handle the data statistically becomes massive. There is little real data to indicate the proper choice of air handling systems. Laminar flow systems with exchange rates of 300 to 600 per hour as compared to the conventional room, which legally has to have 12 changes per hour may not be more effective in infection control. The law of diminishing returns may be operative in laminar flow systems, but the problem becomes a legal one in that everybody feels they have got to be up with the state of the art.

DR. FAVERO: Mr. Michaud, in terms of energy demand, what is the difference in rooms in certain areas in which you get a lot of air movement. How much more energy are we talking about?

MR. MICHAUD: The major additional energy is one of horsepower to move the air. As an example, any room with 25 air changes an hour is about 1600 CFM of air. The laminar flow room becomes 16,000 CFM of air, so I have a magnitude of 10 to 1 of electrical energy just to move the air. I have the same quantities of outside air because my base system is 25 air changes. It also allows me the ability to use outside air when it is cool enough and the cold will allow me to have the proper filtration. It's mainly a horsepower concern, but I wonder if these aren't deleterious effects.

DR. DRAVNIEKS: It is laminar flow when it exits but once it hits any kind of object, it's really not laminar flow because of turbulence. Fast flow doesn't get rid of odors faster

DR. ULRICH: You get turbulence behind every system. White, in Scotland, using his microbubble technique, demonstrated this. He generates very small bubbles into the airstream and then views the bubbles with forward scanners. Many bubbles get behind an object where you have turbulence and just stay there. These systems are all turbulent systems. In the straight-through system, those that get out into the stream and not behind the

barrier are swept out. Even using the microbubble technique of the Agnew people, commercial producers, they produced bubbles about that size to show how air was swept out. There is one sequence on their film where a bubble gets down at the end of the table and it just stays there for the whole sequence. Again, we are sort of fooling ourselves with what we think we are doing with these systems.

Another aspect of energy control in these systems is heat production. Most use HEPA filters. With a HEPA filter you have a very small pore size and as a result the large amount of energy it takes to push air through that filter produces a tremendous amount of heat. Noise level is another undesirable factor.

MR. CHATIGNY: My experience is limited to the number of laminar flow rooms. It isn't just cleanliness of control rooms but the temperature differentials in the rooms become very small. This is one of the comments that I consistently hear from the people who use laminar flow, it's a much more comfortable environment.

Let's assume that we have a laminar flow room with HEPA filters. Most of these are designed around a 1 inch static pressure. Supposing we were to tell you that you could diminish the static pressure to one-tenth of an inch. Would it be economical in an energy sense?

MR. MICHAUD: It's a matter of when is it economical to use energy. I'm certain you can reduce the static pressure and then the energy.

MR. CHATIGNY: Would the energy reduction be almost directly proportional to the pressure drop across...

MR. MICHAUD: Not quite.

DR. SOLBERG: What is the difference in cost between running a laminar airflow room and a 12 air changes per hour ventilated room per year?

MR. MICHAUD: Let me do some calculating.

DR. SOLBERG: I can tell you what one hip infection costs. If the infection rate can be reduced by two cases a year, then it might pay.

DR. ULRICH: There are other costs involved in the laminar flow room. They are very expensive compared to the conventional high-rate filter systems.

DR. SOLBERG: Can't you install a laminar airflow room in another surgical room and recirculate the air?

DR. ULRICH: It does recirculate.

DR. SOLBERG: Always? Then it's less expensive.

DR. FAVERO: The laminar flow room we have in Phoenix takes outside air -- 5 percent makeup air.

DR. ULRICH: You are talking about a straight-through system. Aren't you?

DR. FAVERO: I'm talking about the rate of ventilation in laminar flow clean rooms. If you are talking about a room with a 100 percent complete air change at one time that represents a tremendous cost.

DR. ULRICH: It certainly does and especially in areas with climatic extremes.

DR. FAVERO: You can recirculate 95 percent of the air and expense is related to the operation of the motors driving the air.

DR. ULRICH: We have an unanswered question on comparative costs.

MR. MICHAUD: At a four cent kilowatt hour charge for six hours on the conventional turbulent flow room our electircal unit is about $50 a year.

The same unit on the laminar flow system costs $750 a unit.

DR. SOLBERG: If you can reduce the postoperative wound infection rate in hip implantation by one infection using the laminar flow room, then you might save the cost of several rooms because one infection costs at least $50,000.

MR. MICHAUD: This is where some economics enter in. I still have to buy that system over the other one. We are finding that to be a $30,000 increment.

DR. SOLBERG: That will cost one infection.

DR. ULRICH: You are making the assumption that if you increase the rate flow --

DR. SOLBERG: We don't know that. But if that increased ventilation rate can result in a reduction of only one infection case per year, that pays.

DR. ULRICH: This Minnesota group requests that this workshop point out areas of deficiencies in the air handling not only in surgery but also in the hospital as a whole. Control of other parameters and those that we have just been discussing should be included. Let's try to get into some of the other areas. Mr. Sodergren has indicated from his studies that humidity probably is not a really important parameter.

MR. SODERGREN: Regarding humidity, Mr. Michaud mentioned this morning that the airflow could go down to 5 CFM per person in a hospital. If you are going down so far, and calculate with around two pounds of water from each person per day, it means that we get too much humidity in the air. Probably the humidity will give the limit for how much outside air you need. When you are going down to 5 CFM the humidity will increase too much. I guess that sometimes it will be necessary to take in more

outside air just to keep the level of the humidity correct.

I'm talking about the hospital in general. Mostly, humidity will be too high and you need to take outside air in to reduce the amount of moisture in the air. That means we don't have any problem with too dry air if we are going down with the amount of outside air as much as mentioned.

DR. ULRICH: Mr. Chatigny's level, as I remember it, was anything under 70 percent. Was it maintenance at a level of 70 percent, or less relative humidity?

PANELIST: This is a slightly different standard when the humidity goes as high as 60 percent or higher. All kinds of materials begin to rust. Below 60 percent there is no rusting.

DR. ULRICH: On the basis of what has been said you probably would have to tailor the system for various parts of the hospital. In an intensive care unit where more people are involved, that is, nursing and clinical staff, as compared to other ordinary nursing wards, you would have to probably consider different rates of flow.

MR. MICHAUD: That's very true.

MR. CHATIGNY: Why have you eliminated either the local dehumidification or recirculation dehumidification?

DR. ULRICH: That's another whole area on dehumidification.

MR. MICHAUD: In the summer you have a dehumidification process going.

MR. CHATIGNY: But outside air may be the more costly way of doing it.

MR. MICHAUD: Yes, generally it is.

MR. SODERGREN: If you are going down to the amount of outside air close to what you mention here, 5 CFM per person, I think you would need very little heat for the air you take in during the year. Most of the year you can heat the outside air with just the heat inside the hospital. It's more a question of taking in just as much outside air as needed to keep the right level of temperature and the right level of humidity in the building. These components, humidity and heat, will require as much outside air as needed in order to provide a good level of hygiene.

MR. MICHAUD: To do that I have to have the right to recirculate. That's the key to the whole thing.

MR. SODERGREN: Yes, it is.

MR. MICHAUD: Then I can take my minimum quantities of air, and I am going to use recirculation wherever it is more beneficial to use than outside air in greater volume. It doesn't need to be treated, so I don't have to waste energy on it. I am not allowed to recirculate now except in an operating area under certain given conditions.

MR. SODERGREN: That's very important and I think we agree. By recirculating air in the hospital, we reduce the heat consumption for heating and ventilation next to zero, and only for a short time of the year do we have to add heat. There is heat enough inside the house, but for an even temperature it's necessary to recirculate the air. Outside air is used in a better way by recirculating because people in the hospital are moving from one place to another.

DR. DEROOS: It seems like an important issue is whether or not we can recirculate more air for patient rooms.

DR. SOLBERG: What is the effect on odors?

DR. DRAVNIEKS: Let's assume that we have 20 cubic feet a minute and we want to reduce to 5 cubic feet a minute of new air. The perceived odor intensity would increase by roughly the cube root of four, or 1.59. This is then the factor by which the odor intensity would increase. It's rather a marginal effect. Now, what happens to the threshold? Cutting the ventilation rate from 20 to 5 cubic feet per minute, for the ca e where the odor was at its threshold where 50 percent of the people could detect it may typically make odor detectable by 95 percent of the people. The detection of odor is an individual matter and it depends on the odor source, what kind of odor, and how sensitive is the individual who is exposed to that odor. As far as odor control, it is in the same category as blankets or turning up a thermostat -- all have very individualistic and localized effects. So, cutting the rates down from 20 to 5 CFM would be tolerable.

DR. ULRICH: There was some discussion yesterday on controlling rate of flow and letting humidity float.

MR. CHATIGNY: Because of the broad physiological response to temperature and humidity one could allow humidity to float within prescribed limits on the lower side by the electronic equipment which is highly subject to stray fields and static charge and on the high side by the corrosion factor. Within those limits, I see no physiological reason for strict control. This is a recommendation we ought to discuss.

MR. MICHAELSEN: What do you think the potential low limit could be, 20 percent?

MR. CHATIGNY: I think a 10 to 15 percent range would be quite acceptable in many conditions. Now, obviously, there must be local control of highly specialized considerations.

MR. SODERGREN: We don't have the same kind of odors in all rooms of the hospital, so if you recirculate the air we dilute the odor. If you have the same amount of total air passing through one room and if

you don't have the same kind of odors in the whole hospital the level will be the same in that particular room as it will also be if you use only outside air. Is there any chance that the same odor would be in the whole hospital and so this would be a reason to raise the amount of outside air?

DR. DRAVNIEKS: It is better to isolate the higher odor areas and treat them locally.

MR. CHATIGNY: Rae and Smith have shown that moderate levels are not objectionable to most people.

MR. SODERGREN: Back to the amount of outside air again, I think with the low level you are suggesting, we also get a very low cost for heating, so five, six or seven CFM doesn't really matter. In talking about the emission of odors and humidity, I think that the humidity has the same level in all parts of the hospital. Human beings emit humidity everywhere and the humidity limit establishes the level for the right amount of outside air. It could be 50 percent or it could be 60 percent.

MR. MICHAELSEN: We have to look at the condition of a patient's room alongside of the wall as the condensation process starts on the wall. This is another reason to be careful about a humidity standard.

MR. SODERGREN: Can we state that humidity is the thing to look at regarding how much outside air we have to take in and by doing that know that odors inside the hospital shouldn't be too high?

MR. MICHAUD: Our energy code says that when our outside temperature is minus 14 degrees Fahrenheit, we should not exceed 20 percent relative humidity. To exceed that with a non-renewable resource is verboten. You must be concerned about the condensation on surfaces and behind surfaces of building materials.

MR. CHATIGNY: The question is should we recommend that the humidity within the whole hospital, excluding special local containment areas for special purposes, be allowed to swing within broad limits and do those limits need further study for clear establishment on the low and the high ends. Tentatively, we would say something on the order of 15 to 20 percent on the low end and below 70 percent on the high end.

DR. ANDERSEN: We should avoid condensation, to preserve the building and also to keep away microorganisms that would grow in areas where there is a condensation problem.

MR. CHATIGNY: I would recommend a broader limit to force study because we cannot treat a HVAC system independently of the envelope of the building. It may be that we need a tighter building to avoid the condensation.

DR. ULRICH: Most fungi will not grow at humdidities below 85 percent. However, due to the condensation problems on outside walls, humidities will exceed 85 percent. We should extend your recommendation to establishing studies on the ends of the spectrum and better define what the parameters should be.

MR. CHATIGNY: Allowing RH temperature combinations to float more widely gives the engineer considerable leeway in design and perhaps is a simple, more rapid way of energy conservation.

DR. ULRICH: Another area discussed at some length was particulate generation. Who would like to open the discussion in this area?

MR. CHATIGNY: Carpet problems merit a discussion because that can be a serious problem.

DR. ANDERSEN: Up to now carpets have only been considered important because of bacterial spread. There are two kinds of bacterial growth in carpets: 1) uniform growth, and 2) growth concentrated in spots

where something has been spilled. Most studies done in this field show that very little bacteria is emitted into the air from the carpets. But concerning mites, we do not know about the take off of allergens. We know that in every room where textiles are present allergens from horses, cows, cats, dogs and so on are found in the air and in the carpet. Studies should be done where the content of allergens is measured in the air over carpets in rooms with different activity levels.

DR. ULRICH: Allergens are a number of orders of magnitude smaller than the bacteria, so the bacterial studies really don't relate to these substances. You are talking about particulate size again, with probably a minimum of about a micron up to somewhere around 30 or better, but the particle size could be minutely small in comparison. I know of no studies in this area.

MR. MICHAELSEN: I wonder if we could get back to the recirculation of air, for example, recirculating toilet exhaust systems. What are our hazards, why can't we do it?

DR. ULRICH: It depends upon the area. I have a feeling that our greater problems are comfort problems and removal of noxious gases. In central supply, the ethylene oxide autoclave will be opened during a run, venting the entire gas contents into the air. Special problems arise in special areas.

MR. MICHAELSEN: We need a list of research needs on specific subjects that we could pursue following this Conference.

DR. ULRICH: Perhaps the best way to handle this is to have each panelist provide what he considers to be the major problem in his area.

DR. ANDERSEN: We are now talking about ventilation rates of the same magnitude as in homes and offices. We should look at the procedures used for cleaning in the hospitals because many dangerous chemicals are added to the cleaning agents and in hospitals the chemical environment

is often less favorable than that in many factories. Bacteriologists question the need to use all those disinfectants. We are producing a significant chemical load and we are now down to low ventilation rates. Studies should take place where the use of chemicals is studied.

DR. ULRICH: That's an excellent idea, especially in carpeted areas that have a residual buildup. On hard surfaces it is probably not that important, but from studies by Dr. Vesley, Dr. Favero and the APHA surface sampling group, it is clear that the use of detergents alone was as effective in controlling microbial surface contamination as germicidal detergents.

DR. ANDERSEN: There would be considerable savings. In Denmark, with five million inhabitants we use $13 million disinfectants per year for hospitals. That should not be necessary.

DR. SOLBERG: How much do you use in this country?

DR. ULRICH: It's way overused. In my own institution housekeeping is instructed to use a good detergent and if the germicide costs nothing use it.

DR. SOLBERG: That's an important research field.

DR. ANDERSEN: A second thing is that the Yaglou studies should be redone. This would also be important for other buildings because it was mainly an odor study. Dr. Dravnieks can do a better study today than what was done 40 years ago.

Also, the spreading of skin scales at different humidities is an important question. There has also been some talk about the wound drying, but Dr. Hambraeus told me yesterday that she didn't consider it an area of interest because the surgeons always pour water over the wound.

DR. SOLBERG: Do you know if the isolation procedures you have in this country are necessary? You have standard procedures that have been developed by a national committee with a number of levels. We have three types of isolation facilities. LAF rooms are combined with strict aseptic technique (reversed isolation). These rooms are used for patients with severe immune deficiency diseases, that is patients with combined immune deficiency undergoing bone marrow transplantation. If LAF rooms are available we also use them for patients with agranulocytosis. This isolation facility is only available at the larger hospitals, usually university hospitals. If LAF rooms are not available we use single bedrooms with an airlock. A second isolation facility is a single bedroom with an airlock. These isolation facilities are used in order to prevent airborne infection for patients with tuberculosis, varicellae,measles, pertussis, staphylococcal and streptococcal wound infections. Lastly, are single bedrooms. These isolation rooms are used in order to prevent contact infection. Patients hospitalized in these rooms have postoperative wound infections, salmonellosis, shigellosis, infections with enteropathogenic *E. coli*, acute hepatitis, gas gangrene, for example. In addition to these three types of facilities, we also keep in reserve a small separate building in case patients with particularly dangerous virus infections (ebola or Marburg virus infections) should be admitted to the hospital.

MR. SODERGREN: Recirculation of air is important to the cost of heating in hospitals. We always say we can't trust filters because sometimes they are badly maintained. Why not go out to different hospitals and test the filters to see how they are used, how they work at the moment, and what dangers there are in recirculating air? I mentioned an example when there was no filter at all, but I don't think you will find that in many places. Mostly the filters are in good order. I think we should investigate this.

DR. ULRICH: Would you also include the efficiency of filters in various areas? There is little data on this.

MR. SODERGREN: Yes. As for the humidity inside the hospitals, we should also look at the walls and the windows and see where the cold inside surfaces are to see if there is much work to raising the inside surface temperature where it is lowest.

We should look at the surfaces inside a hospital and see what heat you can store with different walls and ceilings. When you have an open concrete ceiling you can store quite a bit of heat in the concrete from the day to the night and in that way it is possible to reduce the heat load. That is also the case but not to the same extent with carpets.

DR. ULRICH: Would you include air circulating changes as the need in an area changes?

MR. SODERGREN: That's important, too.

DR. ULRICH: You would not have to ventilate at the same rate over 24 hours. A study of traffic control during visiting hours compared to the middle of the night may result in considerable savings.

DR. DRAVNIEKS: The odorous emission problem would not be necessarily grossly enhanced if you start cutting the circulation. If the circulation includes carbon filters, the odor problem may not be increased at all. I haven't seen data on the odorous emissions sources in hospitals: what are the typical sources; how much would the demand for nonodorous air be, or what is the demand of fresh air to reduce the odors to threshold values? The odorous emission intensity or various frequencies of occurence of these sources is something we do not know. A survey type collection of data as to what is the extent and frequency of the odor problems is advised. Complaint statistics are useful, but difficult to estimate whether the problem actually exists. Odor complaints are frequently made when there may be no odor to measure. It may be psychosomatic. Some data base on odor sources in hospitals would be useful.

DR. DEROOS: What kind of research do we need to solve this question about toilet exhaust, recirculation, or reuse? Is recirculating into the total air stream of a hospital important from an odor point of view?

DR. DRAVNIEKS: Some measurements need to be made. Odor samples should be collected from the source like bag samples of air from the bathrooms. Evaluation can be made of the dilution threshold of these odors, so you would know the demand of clean air to reduce typical peak loads. You must make an odor sources inventory.

Also, in reference to chemicals, it seems that there is an unnecessary amount of fragrances and substances used. As far as I'm concerned, the less fragrances and aromas in the preparations of floor wax the better. Aside from odors, whenever the floor is vacuumed there is a tremendous amount of dust thrown around. Perhaps a central vacuuming system would be better so that the dust goes into a duct in the wall and is treated separately.

MR. CHATIGNY: I would like to see some actual particle size data on the secondary aerosols containing those allergens from the mites. What I have seen is not sufficiently definitive to allow us to make a judicious selection of filtration or air cleaning systems. The aerodynamic size and the physical size are entirely different and yet we collect them on the basis of physical size and they travel on the basis of aerodynamic size. A study of secondary particles is beginning to look more and more important to me. Also, I think there is a need for functional area energy audits. We really cannot address whether we should be discussing the OR at length or the wards or the kitchens until we find out where the larger amounts of energy are used.

DR. FAVERO: My suggestions come in the context of epidemiology and microbial contamination and from hearing these discussions, I don't believe lowering ventilation rates is going to have an impact in the hospital operating room in terms of microbial contamination. I would

like to see information completed on such areas as burn units and isolation areas.

DR. HAMBRAEUS: If a filter is not put into the right place the exchange of particles between rooms would be 0.5 percent. This is a very low risk considering that the transfer by our clothes would be at least tenfold. So obviously air would be allowed to recirculate until you have solved the barrier gown problems.

Another area is if you do have a very low ventilation rate you may need to know more about what types of patients we have to isolate. You may need to know more about what type of infections give the heavy -- environmental contamination. It's well know that airborne contamination from burn patients is extremely heavy and some patients with skin diseases also disperse large amounts of bacteria. For patients with wound infections, little is known of what kind of wounds give airborne contamination. Sometimes you find patients will contaminate the air with wounds infected with staphylococci or streptococci. This is probably due to skin contamination. More knowledge is needed of how and when different kinds of infections or treatment give airborne contamination. Little is know about virus.

DR. ULRICH: That would also include such aspects as the type of bandaging. We know ordinary bandages are completely inadequate to control shedding from a wound. The use of probably impervious layers over the tops of bandages might be important.

DR. SOLBERG: What happens when the bandage is wet?

DR. ULRICH: The bacteria passes through but disperses less.

DR. SOLBERG: I would like to add a study on gram negative bacilli which are also prevalent in hospital-acquired pulmonary infections. It has been shown that patients are often colonized with these strains in

the upper respiratory tract before the infections develop. So far, the source and route of transmission for these bacteria are not known. Could they be airborne? These infections occur quite often in intensive care units. The intensive care units represent one of the most critical areas in the hospital and little is known abut the transmission of microorganisms in these units.

DR. ULRICH: There is one area that I have been interested in from several standpoints. The value in outside walls to stop condensation I don't know whether there is data available.

MR. MICHAUD: We know that comfort conditions can be achieved with relation to the outside wall construction and we can determine the mean radiant temperature. The problem with using total radiant heating systems is cost. If I use radiant heating systems, I am almost obligated to use more humidity than otherwise required for conventional conversion systems. Two reasons for this are that dry air destroys furniture, and I should incorporate a cooling system which results in a very complicated and expensive control system to minimize condensation on those panels in the summer.

Also, this test on recirculation can be readily accomplished. There should also be some basic research in the area of odor measurement machinery. Also, is there some way of measuring biological contaminants in the air? Should there become an accepted standard rate of infection at a lower level in a hospital?

DR. DRAVNIEKS: One suggestion has been to measure odor by instruments like sulfur compound detectors. It is difficult because all sulfur compounds are not equally smelly. For specific types of odors you may have specific means of measuring these things. If you want to measure a variety of odorants in air you have a problem.

DR. ULRICH: Sometimes you can on the basis of oxidation reduction levels.

Aldehydes and ketones are oxidizers, whereas, the sulfur compounds tend to be reducers.

MR. CHATIGNY: The problem of odors is one of clearly identifying the sources and types of odors as well as their occurence in hospitals.

DR. DRAVNIEKS: So-called color tubes may have use. These are glass tubes filled with some materials which change colors when reacting with some organisms. They are not too popular but in some cases they work. You pull a certain amount of air through the reagent and you observe the length of discoloration.

MR. BANKS: Well, I think what I have sensed being said is that if we meet the ambient air quality standards we shouldn't have a problem with outdoor air pollutants.

DR. ANDERSEN: Right.

DR. DRAVNIEKS: It's a matter of degradation. Natural oxide levels, ozones, or SO_2 levels go up. It's all the probability of distribution.

MR. SODERGREN: I know that Kethley made some investigation regarding particles and bacteria in the outside air.

MR. BANKS: Was there an association between the outside and inside concentrations?

MR. SODERGREN: Yes.

DR. DEROOS: Research needs seem to have been presented in our discussion on kitchen exhaust and other exhaust areas.

DR. SOLBERG: We did a study some years ago to find out whether a heavy *Staph. aureus* dispenser gave rise to a higher *Staph. aureus* nasal

carrier rate among his roommates than a person who dispersed very few staphylococci. One patient who dispersed about one million *Staph. aureus* particles in the two-hour test, I mentioned earlier, was put together with three patients who were not *Staph. aureus* carriers in a four-bed room. In another four-bed room, a patient who dispersed less than 100 *Staph. aureus* particles were put together with three other patients who were not *Staph. aureus* carriers. The dispersers and non-dispersers remained in bed for approximately one week and were taken care of by separate nurses. Several experiments were performed. Less than 5 percent of the patients who shared the room with a "light" disperser became nasal carriers of the index patient's strain compared to 30 percent of those sharing the room with a heavy disperser.

DR. ULRICH: You can come to a good conceptual opinion as to the danger posed to and by various cancer patients in a hospital. Individuals that are immuno-suppressed are high risk people.

DR. HAMBRAEUS: I thought we were discussing if we can lower the present standards without risk and we are accepting the present standards as a risk that we are willing to run. Perhaps we may want to run away again to much higher standards. The equilibrium concentration in a room is given by $N_e = \frac{nB}{R+S}$ (n = the number of persons, B = the rate of dispersal per person, R = the ventilation rate, S = the rate of loss due to sedimentation) for particles of 0.3 liters per minute is about five times an hour, so as long as R only varies between 2 and 10 N_e will vary only a little.

MR. MICHAELSEN: We are rapidly approaching the adjournment of this most interesting Conference and I regret having to bring this discussion to an end. Our task has been to see if there is a basis for reducing ventilation standards in hospitals for the purpose of conserving energy without having an adverse effect on the well being of the patient or the

hospital staff. We probably all have a better understanding of the enormity and complexity of this task. I will not attempt to summarize what has been said in the last three days; rather let me express the profound thanks of our research team to you as a group and individually for your willingness to help us reassess hospital ventilation standards in light of the needs for energy conservation.

Our task is just beginning and you will have a continuing involvement with this project until its conclusion. We will prepare a verbatim transcript and then with your input we will prepare an edited version. We will also share with you a summary of research needs to serve as a basis for suggesting changes in hospital ventilation standards. Your comments will be appreciated.

In addition we will prepare a summary of our literature search and again we will appreciate your comments. We will submit to you a series of short questionnaires asking for your opinion on a number of the factors of the total problem which we have been discussing these past few days.

It is our hope to reconvene this group in 1979 to help us review what has transpired and to arrive at final recommendations. Thank you again your willingness to be a part of this effort. We wish you a safe journey home.

The Conference stands adjourned.

APPENDIXES

Appendix A: Conference Agenda and Project Staff

Tuesday, February 21

8:30 a.m. -- 9:00 a.m.	Continental Breakfast
9:00 a.m. -- 10:00 a.m.	Welcome Dr. Roger L. DeRoos Introduction Conference Objectives Professor George S. Michaelsen
10:00 a.m. -- 11:00 a.m.	Infectious Agents: Role of Airborne Biological Agents Dr. Claus O. Solberg
11:00 a.m. -- 12:00 Noon	Physical Agents: Temperature, Humidity Air Motion, Radiant Energy Mr. Robert Michaud
12:30 a.m. -- 1:30 p.m.	Lunch
1:45 p.m. -- 2:45 p.m.	Discussion: Infectious Agents Dr. Hambraeus
2:45 p.m. -- 3:00 p.m	Break
3:00 p.m -- 4:00 p.m.	Discussion: Physical Agents Mr. David Sodergren
4:00 p.m. -- 5:30 p.m	Discussion Professor George S. Michaelsen
6:00 p.m. -- 7:00 p.m	Dinner
8:00 p.m. --	Discussion Professor George S. Michaelsen

Wednesday, February 22

8:30 a.m. -- 9:00 a.m.	Continental Breakfast
9:00 a.m. 10:00 a.m.	Chemical Contaminants: Sources and Problems Arising Therefrom Dr. Ib Andersen
10:00 a.m. 11:00 a.m.	Aesthetic Factors: Odors, Air Fresheners, Air Ionization, Stale and Fresh Air Mr. Mark Chatigny Dr. Andrew Dravnieks
11:00 a.m. 12:00 Noon	Discussion Professor George S. Michaelsen
12:00 Noon 1:15 p.m.	Lunch
1:30 p.m. 2:30 p.m.	Discussion: Chemical Contaminants Dr. Martin Favero
2:30 p.m. 2:45 p.m.	Break
2:45 p.m. 3:45 p.m	Discussion: Aesthetic Factors Mr. Robert Banks
3:45 p.m. 5:00 p.m.	Discussion Professor George S. Michaelsen
5:30 p.m. -- 10:30 p.m.	Chanhassen Dinner Theatre Reservations

Closed Session: Thursday, February 22

8:30 a.m. -- 9:00 a.m.	Continental Breakfast
9:00 a.m. -- 11:30 a.m.	Discussion: Conclusions Dr. John Ulrich
11:30 a.m. -- 12:30 Noon	Lunch
	Final Discussion Adjournment Professor George S. Michaelsen

University of Minnesota Project Staff

Roger L. DeRoos
Associate Professor and
Principle Investigator
School of Public Health
Environmental Health & Safety
University of Minnesota
Minneapolis, Minnesota 55455

George S. Michaelsen
Professor Emeritus and
Primary Consultant
School of Public Health
University of Minnesota
Minneapolis, Minnesota 55455

Robert S. Banks
Research Fellow and
Project Coordinator
School of Public Health
University of Minnesota
Minneapolis, Minnesota 55455

Jonna L. Anderson
Research Specialist
School of Public Health
University of Minnesota
Minneapolis, Minnesota 55455

Kay Cady
Assistant Editor and
Conference Coordinator
School of Public Health
University of Minnesota
Minneapolis, Minnesota 55455

Jean Casey
Secretary
School of Public Health
University of Minnesota
Minneapolis, Minnesota 55455

Appendix B: Advisory Panel

Dr. Ib Andersen
Institute of Hygiene
University of Aarhus
DK 8000 Aarhus C
Denmark

Mr. Mark A. Chatigny
Chairman
Environmental Biology Department
Naval Laboratory
Naval Supply Center, Building 844
Oakland, California 94625

Dr. Andrew Dravnieks
211 Tampa Street
Park Forest, Illinois

Dr. Martin Favero
Center for Disease Control
Field Station
Phoenix, Arizona 85014

Dr. Anna Hambraeus
Assistant Professor
Department of Clinical Microbiology
Akademiska Sjukhuset
750 14 Uppsala 14
Sweden

*Mr. George F. Mallison
Assistant Director
Bacterial Diseases Division
Bureau of Epidemiology
Center for Disease Control
Atlanta, Georgia 30333

Mr. Robert Michaud
President
Michaud, Cooley, Hallberg, Erickson
and Associates, Inc.
310 Plymouth Building
Minneapolis, Minnesota 55402

Mr. David Sodergren
Paul Petersson Konstruktionsbyra AB
Barnhugatan 3
111 23 Stockholm
Sweden

Dr. Claus O. Solberg
University of Bergen
Haukeland Hospital
Department of Medicine B
Bergen, Norway

Dr. John Ulrich
Department of Microbiology
Medical School
University of New Mexico
Albuquerque, New Mexico 87131

*Mr. Mallison was unable to attend the Conference

HYGIEJNISK INSTITUT · AARHUS UNIVERSITET
INSTITUTE OF HYGIENE, UNIVERSITY OF AARHUS, DK 8000 ARHUS C, DENMARK

IA/krc. 1978-05-17.

Mrs. Kay Cady,
1158 Mayo Building,
School of Public Health,
University of Minnesota,
Minneapolis,
MN 55455,
U.S.A.

DR. IB ANDERSEN

With reference to your letter of April 13th 1978 I enclose my curriculum vitae.

Born	1936	
MD	1961	
	1961-1963	Internships
	1963-1968	Assistant professor of Hygiene, University of Aarhus, Denmark
	1966	DPH, Copenhagen
	1968-	Associate professor of Hygiene, University of Aarhus, Denmark
	1971	Thesis
	1971-	Consultant in Occ. Health
	1977-	Member of the Danish Academy of Technical Sciences.

Author of 60 papers, mainly on building hygiene and occupational health. Main interest is airborne pollutants and their health effects.

Yours sincerely,

Ib Andersen, M.D.

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211 TAMPA STREET
PARK FOREST, ILLINOIS 60466, U.S.A.

ANDREW DRAVNIEKS, PH.D., DIRECTOR
TELEPHONE (312) 748-7213

Ms. Jean Casey
University of Minnesota

DR. ANDREW DRAVNIEKS

Here is my short curriculum vitae:

Andrew Dravnieks, Ph.D.

Education: University of Latvia, chemical engineer 1938; University of Marburg, 1946; Illinois Institute of Technology, PhD. in physical chemistry, 1949.
Experience: taught at the University of Latvia; was technical director of Riga Paint and Chemical Co in Latvia; research associate with Illinois Institute of Technology, 1947-1949; head, corrosion and electrochemical reactions, Engineering Research Department, Standard Oil of Indiana 1949-1960; scientific advisor and later technical director of Odor Sciences Center, IIT Research Institute 1960-1977.
Publications, Patents: over 90 papers, books, and patents, with 50 of these dealing with odor measurements, analysis, and classification, and detection of low concentrations of organic vapors in air.

MARK A.CHATIGNY

Mark A. Chatigny is chairman of the Environmental Biology Department in the School of Public Health, University of California, Berkeley. The facility is located at the Naval Biomedical Research Laboratory, Oakland, California.

Mr. Chatigny received his B.S. at Berkeley in 1949 and has taken graduate courses in nuclear physics, engineering, mathematics, and chemistry. While working on his degree, Mr. Chatigny worked in the Department of Bacteriology at Berkeley. In 1950, Mr. Chatigny joined the Naval Biomedical Research Laboratory as an assistant research engineer. He was named chairman in 1969.

As a research engineer, Mr. Chatigny is interested in aerobiology instrumentation, laboratory safety, and bioengineering, with specific interest in apparatus for studying airborne infection and simulating natural environments, microscopic scanning and photometric techniques for detection and indentification of airborne microorganisms, and the design of contamination control techniques and microbiology laboratories.

Mr. Chatigny's professional honorary memberships include the Biohazards Control and Containment Working Group of the National Cancer Institute, the National Safety Council, the Institute of Electrical and Electronic Engineering, the American Institute of Biological Sciences, and The Tripartite Reference Standard Aerosol Working Group.

CURRICULUM VITAE MARTIN S. FAVERO

Martin S. Favero, Ph.D.

Date and Place of Birth: May 3, 1937, at Butte, Montana

Marital Status

Married, four children

Education

1959 - B.S. Gonzaga University, Spokane, Washington
Major Biology; minors Chemistry and Philosophy
1961 - M.S. Washington State University, Pullman, Washington
Bacteriology and Public Health
1964 - Ph.D. Washington State University, Pullman, Washington
Bacteriology

College Activities and Awards

1955 - Edmund Ignatious Rice Award
1958 - Who's Who in American Colleges and Universities
1957-58 - Forum Committee Chairman
1957-58 - Junior Class Representative
1958-59 - Student Body President
University orchestra and intramural sports

Employment

1957-59 - Teaching assistant, Gonzaga University
1957-59 - Research assistant to Dr. E. Foubert, Hollister-Stier Company, Spokane, Washington
1959-61 - Teaching assistant, Washington State University
1961-64 - Research assistant, Washington State University
1964- - Research microbiologist, Phoenix Field Station Section, CDC PHS, Phoenix, Arizona
1966- - Chief, Planetary Quarantine Unit, Phoenix Field Station Section
1967- - Acting Chief, Phoenix Field Station Section
1968- - Chief, Applied Microbiology and Planetary Quarantine Section, and Assistant Chief, Phoenix Laboratories
1972-74 - Chief, Environmental Microbiology Section, and Assistant Chief, Phoenix Laboratories
1974- - Deputy Director, Phoenix Laboratories Division, and Chief, Field Investigations Branch

Professional Societies and Activities

American Society for Microbiology. President, Arizona Branch, July 1, 1967 to June 30, 1968

American Association for Contamination Control. Board of Directors, Western Region, 1967-1968
Biological Contamination Control Committee, American Association for Contamination Control
Subcommittee I, Dry Heat Sterilization, of the Planetary Quarantine Committee, A.I.B.S.
Subcommittee on Laboratory Methods for the Examination of Water and Other Environmental Samples, International Association of Milk, Food and Environmental Sanitarians, Inc.
Surface Contamination Committee, Laboratory Section, American Public Health Association. Chairman of subcommittee on Spacecraft Sterilization 1966 to 1973. 1973 - Committee Chairman.
Preliminary Examination Team, Lunar Sample Receiving Laboratory, Manned Spacecraft Center, Houston, Texas.
Associate to Interagency Committee on Back Contamination
Sigma Xi
Alpha Sigma Nu (Honorary Jesuit Fraternity)
American Public Health Association Task Force on Swimming Pool Standards, 1971 to present.
Editorial Board, Applied Microbiology, 1972-1975.
Editor, Applied and Environmental Microbiology, 1976-
Member, Device Sterility Subcommittee of the Panel on Review of General Hospital and Personal Use Devices, Food and Drug Administration
Member, United States Pharmacopeial Advisory Panel on Microbiology

Research Interests

Environmental microbiology; sterilization and disinfection; planetary quarantine; nosocomial infections

Languages

French and German

Awards

Superior Service Award - 1971, Health Services and Mental Health Administration, DHEW
Emmett J. Culligan Award - 1976, World Water Society

PUBLICATIONS AND PRESENTATIONS

Martin S. Favero

1. Favero, M. S., C. H. Drake, and G. B. Randall. 1964. Use of staphylococci as indicators of swimming pool pollution. Publ. Hlth. Rpts. 79: 61-70.

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17. Puleo, J. R., and M. S. Favero. Recovery of viable microorganisms from solids. Presented at the Arizona Branch of the American Society for Microbiology, December 11, 1965.

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CURRICULUM VITAE

ANNA M. HAMBRAEUS

ANNA Margareta HAMBRAEUS, born Fajerson

Born:	Karlstad, Sweden. May 11, 1936
Citizen of:	Sweden
Visa status:	
Married:	Leif Magnus Hambraeus, June 21, 1959
Children:	Sofia, July 4, 1962; Katarina, November 10, 1964; Torkel, July 2, 1967; and Joakim, March 3, 1969
Address:	Lugnesberg, Uppsala-Näs, S-755 90 Uppsala, Sweden
Position:	Assistant Professor and Consultant, Department of Hospital Hygiene, University Hospital, Uppsala, Sweden

Education

Studentexamen, Statens Normalskola, Stockholm, Sweden. May 1955

Medicine kandidatexamen (Bach Med) Caroline Institute, Stockholm, Sweden. May 1962

Presentation of thesis for doctor's degree, University of Uppsala, Sweden. May 1973
(Title: Spread of Staphylococcus aureus in a burns unit)

Assistant Professor of Clinical Bacteriology, University of Uppsala, Sweden (honorary degree), 1973

Academic and professional positions

1963	Underläkare (Resident) at the Department of Psychiatry, at Danderyds Hospital, Stockholm (2 mths 3 days)
1963	Underläkare (Resident) at the Department of Dermatology, Caroline Hospital, Stockholm (3 mths 6 days) and Södersjukhuset, Stockholm (1 month 29 days)
1963-64	Underläkare (Resident) at the Department of Bacteriology, Danderyds Hospital, Stockholm (8 mths 6 days)
1965	Underläkare (Resident) at the Blood Centre, University Hospital, Uppsala (1 month 25 days)
1965	Underläkare (Resident) at the Department of Dermatology, University Hospital, Uppsala (2 mths)
1966-1968	Junior assistant, Institute of Medical Microbiology, University of Uppsala (2 yrs 6 mths)
1968-1971	Assistant at the Institute of Medical Microbiology, University of Uppsala (3 yrs)

1971-1973	Predoctor fellowship at Försvarsmedicinska Forsknings-delegationen (The Swedish Delegation for Applied Medical Defense Research)
1973-1974	Postdoctor fellowship at Försvarsmedicinska forsknings-delegationen (The Swedish Delegation for Applied Medical Defense Research)
1973-1974	Research fellow in medicine at Harvard College, Boston (9 mths)
1974-1976	Reader and consultant at Huddinge Hospital, Stockholm (2 yrs 1 month)
1976-	Head of the Department of Hospital Hygiene, University Hospital, Uppsala

Publications

1. En kemisk metod för påvisande av urinvägsinfektioner. A. Hambraeus, C. Henning & B. Mellin. Sv. Läkartidning 62, 1226, 1965.
2. Typning av Haemophilus influenzae. A. Hambraeus. Nordisk Medicin 81, 656, 1969.
3. The epidemiology of Staph. aureus in a modern burns ward. Paper presented at the Third International Congress on Research in Burns, Prague, September 1970.
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5. Spread of Staphylococcus aureus in a burns unit. A. Hambraeus. Acta Universitatis Upsaliensis, May 1973.
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11. Measurement of airborne exposure to infection in a burns unit. G. Laurell & A. Hambraeus in Airborne transmission and airborne infection. IV. Int. Symp. on Aerobiology, Enschede, the Netherlands. (Eds. J.F.pH. Hess & K.C. Winkler). Oosthoek Publ. Co., Utrecht, 1973, p. 462.

12. Spread of bacteria in a hospital. A. Hambraeus, in Cephalosporins, dimensions and future. Proc. Meeting on Cephalosporins, Karolinska sjukhuset, Stockholm. May 1973. (Ed. B. Edselius). Excerpta Medica, Amsterdam 1974, p. 36.

13. The transfer of bacteria through protective clothing. A. Hambraeus. Proceedings of the R3 Association 1975 Symposium. Contamination control to benefit man and product, 2-4 april, 1975, at Gothenburg.

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16. Surveillance of hospital infections: at the bedside or at the bacteriological laboratory? A. Hambraeus & A.-S. Malmborg. Scandinavian Journal of Infectious Diseases 9, 289, 1977.

17. Airborne contamination and postoperative infection after total hip replacement. A. Schwan, S. Bengtsson, A. Hambraeus & G. Laurell. Acta Orthopedica Scandinavica 48, 86, 1977.

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1. Effect of ventilation on airborne bacteria and transfer of airborne particles. Journal of Hygiene (Cambridge) 79, 121, 1977.

2. Effect of a zoning system on contamination of floors and other surfaces. Journal of Hygiene (Cambridge) 80, 57, 1978.

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GEORGE M. MICHAELSEN

CURRICULUM VITAE

NAME: George S. Michaelsen, 2738 West River Road, Minneapolis, MN. 55406

DATE OF BIRTH: January 28, 1909

CITIZENSHIP: United States of America, (Willmar, Minnesota)

MARITAL STATUS: Married, four children

EDUCATION:
Augsburg College, Minneapolis, 1927-29
University of Minnesota, 1927-32, B.C.h.E.
University of Minnesota, 1932-35, M.S. in Chemical Engineering
University of Minnesota, 1935-36, Additional graduate work in Public Health

EMPLOYMENT:

1935	Assistant Sanitary Engineer, Minnesota Dept. of Health
1936	Research Engineer, Standard Oil Development Co., Baton Rouge, Louisiana
1937-1946	Public Health Engineer I, II, III, Minnesota Dept. of Health, Generalized experience in all aspects of environmental health, but mostly in occupational health.
1946-1953	Associate Chief, Industrial Health Section, Minnesota Department of Health
1953-1974	Assistant Professor, Associate Professor, and Professor, School of Public Health, and Director, Division of Environmental Health and Safety, University Health Service, University of Minnesota
1974-1976	Professor, School of Public Health, Occupational Health Engineer, University Health Service
1976-Date	Professor Emeritus, School of Public Health, University of Minnesota
1976-Date	Expert, National Cancer Institute, Bethesda, Maryland

ENGINEERING REGISTRATION AND ACCREDITATION:

Minnesota Chemical Engineer #1772
Diplomate, American Academy of Sanitary Engineers #176
Certified by the American Board of Industrial Hygiene #318

PROFESSIONAL ASSOCIATIONS:

American Conference of Governmental Industrial Hygienists
American College Health Association
American Public Health Association
Minnesota Public Health Conference
National Safety Council - Campus Safety Association

COMMITTEE POSITIONS:

1. American Public Health Association, Hospitals Facilities Committee
2. American Association for Contamination Control - Hospital Committee

3. American Hospital Association Representative on the Ventilation Committee, National Fire Protection Association
4. American Public Health Association - National Sanitation Foundation Joint Committee on Hospital and Laboratory Equipment
5. Joint Commission on Accreditation of Hospitals - Advisory Committee on Standards
6. American Public Health Association - National Sanitation Foundation Joint Committee on Biohazard Cabinetry.
7. Biohazards Control and Containment Working Group, Special Virus Cancer Program, National Cancer Institute, 1971-1973

SPECIAL APPOINTMENTS:

1. Member, Minnesota State Board of Health Advisory Committee on Radiological Safety
2. Member, Minnesota State Board of Health Advisory Committee on Poison Information Center
3. Chairman, Board of Trustees, Riverside Center, Inc., Minneapolis
4. Member, Board of Regents, Augsburg College, Minneapolis, Minnesota, 1946-1970
5. Member, Board of Trustees, Lutheran Deaconness Hospital, Minneapolis, 1946-date
6. Member, Board of Governors, Lutheran Institute for Human Ecology, Chicago, 1962-1974

HONORS:

1. Environmental Health Class Award for excellence of graduate instruction and progress in the professional development of students, 1969
2. Augsburg College Distinguished Alumnus Award, 1969.

PUBLICATIONS

(G. S. Michaelsen)

1. Kabler, P.; Pierce, G. O.; and Michaelsen, G. S., "Comparative Resistance of Recently Isolated and Older Laboratory Strains of E. Typhosa to the Action of Chloramine." Journal of Bacteriology. Vol. 37 (1939).

2. Michaelsen, G. S., "Industrial Disease Control." Minnesota Technolog. Vol. XXII:178 (1942).

3. Park, W. E.; Michaelsen, G. S., "Leaded Gasoline Used in Carbon Blasting Poisons Mechanic." Occupational Health. October 1952.

4. Michaelsen, G. S., "Radiation Hazards for Morticians." Mid-Continent Mortician. Vol. XXIII, July 1953.

5. Michaelsen, G. S.; Park, W. E., "Asphyxiation in Street Manholes." Public Health Reports. Vol. 69, No. 1, January 1954.

6. Michaelsen, G. S., "The Health Service and the Safety Program." Safety Monographs for Colleges and Universities No. 2. First National Conference on Campus Safety, National Safety Council, 1954.

7. Michaelsen, G. S., "Housekeeping Hazards and How to Avoid Them." Modern Hospital. Vol. 88, No. 1, January 1957.

8. Michaelsen, G. S., "Environmental Health and Safety - Occupational Hazards That Can Be Overcome." Hospitals, J.A.H.A. Vol. 31, No. 22, November 16, 1957.

9. Michaelsen, G. S., "Occupational Health at a University." Public Health Reports. Vol. 73, No. 10, October 1958.

10. Greene, V. W.; Bond, R. G.; and Michaelsen, G. S., "Air Handling Systems Must Be Planned to Reduce the Spread of Infection." Modern Hospital. Vol. 95, No. 2, August 1960.

11. Greene, V. W.; Vesley, D.; Bond, R. G.; and Michaelsen, G. S., "The Engineer and Infection Control." Hospitals, J.A.H.A. Vol 34, September 1, 1960.

12. Bond, R. G.; Michaelsen, G. S.; Scheffler, G. L.; Stauffer, L. D.; and Wollan, R. O., "Environmental Health Needs in Colleges and Universities." American Journal of Public Health. Vol. 51, No. 4, April, 1961.

13. Michaelsen, G. S., "When Designing Operating Room Ventilation." ASHRAE Journal. October 1961.

14. Michaelsen, G. S., "The Design and Maintenance of Operating Room Air Conditioning and Ventilation Systems." American Journal of Public Health. Vol. 51, No. 12, December 1961.

15. Michaelsen, G. S., "Ventilation System Maintenance Practices: Report of a Survey." Hospitals, J.A.H.A. Vol 36, February 1962.

16. Steere, N. V.; Ferris, B. G.; Michaelsen, G. S.; Morris, J.; and Wollan, R.O., "Present Day Issues in Environmental Health, Safety and Occupational Health: A Panel Presentation." Student Medicine. Vol. 10, No. 4, April 1962.

17. Greene, V. W.; Vesley, D.; Bond, R. G.; and Michaelsen, G. S., "Microbiological Contamination of Hospital Air. I. Quantitative Studies, II. Qualitative Studies." Applied Microbiology. Vol. 10, No. 6, November 1962.

18. Michaelsen, G. S., "Environmental Sanitation." Annual Administrative Reviews, Hospitals, J.A.H.A., Vol. 37, April 1963.

19. Bond, R. G.; Michaelsen, G. S.; Bosch, H. M., "Training Qualified Engineers for a Hospital Career." Hospitals, J.A.H.A., Vol. 37, May 1963.

20. Michaelsen, G. S. and Vesley D., "Industrial Clean Rooms vs. Hospital Operating Rooms." Air Engineering, Vol. 5, No. 9, September 1963.

21. Michaelsen, G. S., "Design of Linen Chutes to Reduce the Spread of Infectious Organisms in Hospitals." Final Report under Contract PH 86-62-94, Division of Hospital and Medical Facilities, Public Health Service, October 1963.

22. Michaelsen, G. S., "Environmental Sanitation." Annual Administrative Reviews, Hospitals, J.A.H.A., Vol. 38, April 1964.

23. Vesley, D. and Michaelsen, G. S., "Application of a Surface Sampling Technique to the Evaluation of Bacteriological Effectiveness of Certain Hospital Housekeeping Procedures." Health Laboratory Science. Vol. 1, No. 2, April 1964.

24. Michaelsen, G. S., "Waste Handling." Proceedings, National Conference on Institutionally Acquired Infections, Public Health Service Publication No. 1188, 1964.

25. Bond, R. G. and Michaelsen, G. S., "Bacterial Contamination from Hospital Solid Waste." Final Report, Research Grant EF 00007-04, National Institutes of Health, August 1964.

26. Michaelsen, G. S., "Designing Linen Chutes to Reduce Spread of Infectious Organisms." Hospitals, J.A.H.A., Vol. 39, March 16, 1965.

27. Keenau, K. M.; Halbert, M. M.; Bearman, J. E.; and Michaelsen, G. S., "Some Statistical Problems in the Standardization of a Method for Sampling Surfaces for Microbial Contamination." Health Laboratory Science. Vol. 2, No. 4, October 1965.

28. Michaelsen, G. S., "What is Campus Safety." Safety Monographs for Colleges and Universities No. 20. Twelfth National Conference on Campus Safety, National Safety Council, 1965.

29. Michaelsen, G. S. and Vesley, D., "Disposable Hospital Supplies, Some Administrative and Technical Implications." Hospital Management. Vol. 101, January 1966.

30. McDade, J. J.; Favero, M. S.; and Michaelsen, G. S., "Environmental Microbiology and the Control of Microbial Contamination." N.A.S.A. Conference on Spacecraft Sterilization, Pasadena, California, Nov., 1965, Spacecraft Sterilization Technology. N.A.S.A. SP. 108, 1966.

31. Michaelsen, G. S.; Ruschmeyer, O. R.; and Vesley, D., "The Bacteriology of Clean Rooms." Final Report under Grant NSG 643, National Aeronautics and Space Administration, July 1966.

32. Michaelsen, G. S. and Vesley, D., "Dissemination of Airborne Microorganisms in an Institutional Environment." Surface Contamination. Proceedings of a Symposium held at Oak Ridge, Tennessee, June 1964, Pergamon Press, 1966.

33. Vesley, D. and Michaelsen, G. S., "A Technique for Measurement of Microbial Contamination on Flat Surfaces." Surface Contamination. Proceedings of a Symposium held at Oak Ridge, Tennessee, June 1964, Pergamon Press, 1966.

34. Michaelsen, G. S., "Environmental Health and Safety - The Minnesota Story." Journal Lancet, January 1967.

35. Michaelsen, G. S.; Vesley, D.; Halbert, M. M., "Laminar Flow Studied As Aid In Care of Low Resistance Patients." Hospitals, J.A.H.A. Vol. 41, June 16, 1967.

36. Michaelsen, G. S., "Unknowns in Hospital Contamination Control." Contamination Control. Vol. 7, No. 4, April 1968.

37. Michaelsen, G. S.; Vesley, D.; Sorenson, S. D.; and Runkle, R. S., "Biological Evaluation of a Minimum Turbulence Air-Flow System for Patient Isolation." Journal of the American Association for Contamination Control. Vol. 1, No. 1, June 1968.

38. Michaelsen, G. S., "Microbial Contamination in Surgical Suites." Proceedings of the National Planning Conference on Designing for Asepsis. PB 177 281. U.S. Department of Health, Education, and Welfare, Public Health Service, May 6-7, 1964.

39. Michaelsen, G.S.; Halbert, M.M.; Sorenson, S.D.; and Vesley, D., "Development of an Open Isolation System for the Care of Low Resistance Hospital Patients." Final Report under contract PH 43-65-999, National Cancer Institute, August 1968.

40. Ulrich, J.A.; Cribbs, W.M.; and Michaelsen, G.S., "Recirculation of Air in Operating Rooms." Final Report under Grant PH 108-65-26, Division of Hospital and Medical Facilities, Public Health Service, August 1968.

41. Michaelsen, G.S., "Occupational Health on Campus." Safety Monographs for Colleges and Universities No. 25. Fifteenth National Conference on Campus Safety, National Safety Council, 1968.

42. Michaelsen, G.S., "Solving the Problem of Contaminated Air." Plant Operating Management. Vol. 84, No. 2, February 1969.

43. Vesley, Donald, Michaelsen, G.S., and Levitan, Alexander A., "The Application of Laminar Flow Rooms to Patient Isolation." Germ-Free Biology, Plenum Press, 1969.

44. DeRoos, Roger L., and Michaelsen, G.S., "Use of the Barometric Loop for Protection of Potable Water Systems." The American Plumbing Engineer, June 1969.

45. Michaelsen, G.S., "Laminar Flow as a Contamination Barrier." Medical Tribune. Vol. 10, No. 32, April 1969.

46. Bond, R.G., Michaelsen, G.S., DeRoos, R.L., "Environmental Health and Safety in Health Care Facilities." A Textbook, Macmillan Publishing Co., 1973.

47. Ulrich, J.A., Cribbs, Wm., Michaelsen, G.S., "Recirculation of Air in Operating Rooms." Ashrae Journal, August, 1974.

48. Michaelsen, G.S., "Envaluating the Hospital Environment" Hospitals, J.A.H.A. Vo. 49, No. 9. May 1, 1975.

Robert L. Michaud, P.E.
President and Chief Operating Officer
Michaud, Cooley, Hallberg, Erickson & Associates, Inc.
Consulting Engineers

EDUCATION:
Bachelor of Science in Mechanical Engineering, with Minor in Business Administration, University of Minnesota, 1948

PROFESSIONAL:
Minnesota Consulting Engineers Council, Past President & Present Member, Board of Directors
American Consulting Engineers Council
American Society of Heating, Refrigeration and Air Conditioning Engineers, Past Member of Board of Directors, Member of National Education Committee
Minneapolis Engineers Club
Chairman - State of Minnesota Energy Conservation Subcommittee

REGISTRATIONS:
Registered Professional Engineer of Minnesota and 15 other States

EXPERIENCE:
Mr. Michaud has been with the firm since its inception in 1948. During this time, he has directed the engineering planning for numerous large scale hospital, office, laboratory, retail, industrial and cultural projects.

Recognized nationally as an authority on energy conservation and recycling technology, Mr. Michaud has lectured extensively on these subjects and has authored articles on these topics as well as environmental protection and owning and operating economies. As chairman of Minnesota's Energy Conservation Sub-Committee, Mr. Michaud is responsible for State Energy Codes. He is also a member of Minnesota's Building Standards Committee.

In recent months he has developed an energy management program that incorporates an energy use budget on a monthly basis with a computerized evaluation of the program each month to account for variables of energy costs, weather, maintenance and operational discipline.

He has done pioneer work in the establishment of rate schedules for the sale of HVAC and resale of electrical services in the shopping center industry as well as determining rate schedules for various central steam and chilled water plants.

In recent years, Mr. Michaud has personally taken charge of design concerned with major commercial and merchandising projects. These include full department stores in the Twin City area with both national and regional affiliation. These projects include

several stores for Daytons, Donaldsons and Powers plus Ridgedale, Rosedale, Brookdale, Southdale, Wayzata and Northtown shopping centers.

He has also developed specialized systems for air conditioning and solar applications as well as central plant installations. These include the new Radisson Plaza Hotel in St. Paul, operating rooms in St. Marys Hospital in Rochester and the IDS Energy Center in Minneapolis.

In addition to prototype design of HVAC systems for Target Stores and numerous elementary schools and commercial banks throughout the area, Mr. Michaud has been extensively involved in energy conservation design innovation for Dayton-Hudson shopping centers, Dayton's Department Stores, more than 50 Target Stores across the country and a master plan for Minnesota Mining Company's new industrial campus to include a central utility plant and distribution system which will use gas, oil, coal and/or solid waste as prime fuel.

DR. CLAUS O. SOLBERG

CURRICULUM VITAE.

Claus Ola Solberg, M.D., Ph.D.

Birth Date: May 19, 1931.

Birth Place: Maalselv, Norway.

Education: M.D.- University of Bergen, Norway 1957.
Ph.D.-University of Bergen, Norway 1965.
Diploma in tropical medicine - Karolinska institutet, Stockholm 1969.

Postgraduate training:

1. Intern, Narvik Hospital, Norway 1958.
2. Assistant Medical Health Officer, Alta, Norway January-June 1959.
3. Private practise, Narvik, Norway July-September 1959.
4. Resident, Departments for Neurology, Medicine A and B, University Hospital, Bergen, Norway October 1959 - October 1961.
5. Research Fellow, Medical Department B, University Hospital, Bergen, Norway November 1961 - June 1964.
6. Senior resident, Medical Department B, University Hospital, Bergen July 1964 - July 1969.
7. Postdoctoral research fellow University of Minnesota August 1969-August 1970.

Academic Positions:

1. Teaching fellow in medicine, University of Bergen 1965 - 1969 (Department of Internal Medicine).
2. Associate Professor of Medicine, University of Bergen, since August 1970 (Department of Internal Medicine).
3. Visiting Professor of Medicine, University of Utah Medical Center October-December 1977 (Department of Pathology).

Hospital Appointments:

1. Medical staff, University Hospital, Bergen 1959-1961.
2. Attending physician, University Hospital, Bergen 1964 - present.

3. Consultant in infectious diseases, University Hospital, Bergen 1970 - present.

Boards, Committees, Societies:

President Norwegian Society of Infectious Diseases 1975 - present.

Member of Editorial Board, Tidskriftet for Den norske Lægeforening.

Council Member, Christian Michelsens institutt, Bergen, (Research institute).

Member Norwegian Society for Hospital Infection 1971 - 1975.

Member of several National and International medical societies.

Honors and Awards:

International postdocteral research fellowship 1969-1970. U.S. Department of Health, Education and Welfare.

Søren Falch og Øyenlæge Sigurd Falch'S medical research award. University of Bergen 1975.

Approximately 20 quest lectures at various universities and international meetings (se enclosed list of main lectures).

Bibliography: Includes 92 original articles, chapters or monographs in books. In addition, many published abstracts and proceedings of panels. Various infectious diseases, antibiotics and chemotherapy, phagocytosis studies, hospital infections and internal medicine problems are the subject of these publications.

PUBLICATIONS

1. Phenelzine Intoxication.
   J.A.M.A. 1961, 177, 572-573.

2. Nevrologiske komplikasjoner ved parotitis epidemica.
   Nord.Med. 1961, 66, 1350-1353.

3. Forgiftning med Diffenbachia sequina.
   Naturen 1962, 86, 156-159.

4. Polyarteritis nodosa med lungegranulomer.
   T.norske Lægeforen. 1962, 82, 1646-1649 (med Lamvik, J.).

5. Bruk av bonemaskiner på sykehus.
   T.norske Lægeforen. 1963, 83, 341-344 (med Bøe, Johs.)

6. Behandling med nesespray av stafylokokkbærere i sykehus.
   T.norske Lægeforen. 1964, 84, 168-171 (med Bøe, Johs.).

7. Perineal carriers of staphylococci.
   Brit.med.J. 1964, II, 280-281 (med Bøe, Johs., Vogelsang, Th.M. og Wormnes, A.).

8. Behandling av nasale stafylokokkbærere med Fucidin.
   T.norske Lægeforen. 1965, 85, 527-528 (med Bøe, Johs.).

9. Corticosteroid treatment for acute meningoencephalitis. A retrospective study of 346 cases.
   Brit.med.J. 1965, I, 1094-1095 (med Bøe, Johs. og Sæter, T.).

10. A study of carriers of Staphylococcus aureus with special regard to quantitative bacterial estimations.
Acta.med.scand. 1965, suppl. 478. (Avhandling forsvart for den medisinske doktorgrad 5.november 1965).

11. Behandling av alvorlige stafylokokkinfeksjoner.
T.norske Lægeforen. 1967, 87, 6-10.

12. Hjertekomplikasjoner ved parotitis epidemica.
Nord.Med. 1968, 80, 968.

13. Disinfection of the hands of ward personnel. A comparison of six disinfectants.
Acta med.scand. 1968, 184, 417-423.(med Bruun, J.N. og Bøe, Johs.).

14. Alvorlige bakterielle infeksjoner.
T.norske Lægeforen. 1969, 89, 560-564.

15. Glomerulonephritis with initial lung purpura (Goodpasture's syndrome) : Survival of two patients out of four.
Acta med.scand. 1969, 186, 401-406.

16. Methanol poisoning. Report of an unusual case.
J.A.M.A. 1970, 211, 497-499 (med Closs, K.).

17. Carbenicillin therapy of severe Pseudomonas aeruginosa infections.
J.Chron.Dis. 1970, 24, 19-28 (med Kjellstrand, K.M. og Matsen, J.M.).

18. Laminar airflow protection in bone marrow transplantation.
Applied Microbiology 1971, 21, 209-216 (med Matsen, J.M., Vesley, D., Wheeler, D.J., Good, R.A. og Meuwissen, H.J.).

19. Infections with Providence bacilli.
Amer.J.Med. 1971, 50, 241-246 (med Matsen, J.M.).

20. Ectopic alkaline phosphatase production in metastazing ventricular carcinoma.
Scand.J.clin.lab.Invest. 1971, 28, 21-26.(med Romslo,I. og Bjark,P.).

21. Infectious complications in bone marrow transplant patients.
Brit.med.J. 1971, I, 18-23.(med Meuwissen,H.J., Needham,R.N., Good,R.A. og Matsen,J.M.).

22. Protection of phagocytized bacteria against antibiotics. A new method for the evaluation of neutrophil granulocyte functions.
Acta med.scand. 1972, 191, 383-387.

23. Nedsatt resistens mot infeksjoner. Fagocytosen.
T.norske Lægeforen. 1972, 92, 80-82.

24. Infeksiøse komplikasjoner ved benmargstransplantasjoner.
T.norske Lægeforen. 1972, 92, 87-89.

25. Nosokomiale stafylokokkinfeksjoners epidemiologi.
T.norske Lægeforen. 1972, 92, 584-587.

26. Nosokomiale infeksjoner - hygieniske og kjemoterapeutiske aspekter.
T.norske Lægeforen. 1972, 92, 597-599.(med Lystad,A., Malm,O.J. og Ulstrup,J.C.).

27. Nyere antibiotica.
Medicinsk Årbog XV, pp.111-122. Munksgaards Forlag, København 1972. (med Madsen,S.T.).

28. Enhanced susceptibility to infection. A new method for the evaluation of neutrophil granulocyte functions.
Acta path.microbiol.scand. Section B. 1972, 80, 10-18.

29. Evaluation of neutrophil granulocyte functions.
Acta path.microbiol.scand. Section B. 1972, 80, 559-563.

30. Neutrophil granulocyte function in bacterial infections.
Lancet 1972, II, 727-730. (med Hellum, K.B.)

31. Aerial dissemination of Staphylococcus aureus by hospital patients : Causes and prevention.
Prevent 1972, I, 43-50. (med Bøe, Johs. og Bruun, J.N.).

32. Control of staphylococcal infection in a surgical department.
Prevent 1972, 1, 33-38. (med Bruun, J.N. og Bøe, Johs.).

33. Cephalexin therapy of lower respiratory tract, soft tissue and bone infections.
Scand.J.Infect.Dis. 1972, 4, 241-243. (med Schreiner, A. og Digranes, A.).

34. Cefalosporinene.
T.norske Lægeforen. 1972, 92, 2355-2357.

35. Hospital-acquired infections. Laminar airflow protection in highly susceptible patients.
Spectrum International 1972, 16, 45-47.

36. Serumkonsentrasjonsmålinger av antibiotika. Metoder og indikasjoner.
T.norske Lægeforen. 1973, 93, 13-16.

37. Influence of anticoagulants on the nitroblue tetrazolium test.
Scand.J.Infect.Dis. 1973, 5, 67-70. (med Hellum, K.B.).

38. Bruk av antibiotika-kombinasjoner.
T.norske Lægeforen. 1973, 93, 1405-1407.

39. Hand carriage of Gram-negative bacilli and Staphylococcus aureus.
Brit.med.J. 1973, 2, 580-582. (med Bruun, J.N.).

40. Positive N.B.T. test in acute viral hepatitis.
Lancet 1973, I, 1181. (med Hellum, K.B.)

41. Gentamicin therapy of severe infections.
Infection 1973, 1, 105-109. (med Schreiner, A.).

42. Influence of incubation time and temperature on the nitroblue tetrazolium test.
Scand.J.Infect.Dis. 1973, 5, 145-147. (med Hellum, K.B.).

43. Clinical rubella after reinfection : False positive reaction of specific HI antibody.
New Engl.J.Med. 1973, 289, 429. (med Haukenes, G. og Haram, K.).

44. Rubella reinfection and the fetus.
Lancet 1973, I, 1313. (med Haukenes, G. og Haram, K.).

45. Behandling av akutt bakteriell meningitt.
T.norske Lægeforen. 1973, 93, 1770-1774.

46. Influence of serum on the bactericidal activity of neutrophil granulocytes.
Acta path.microbiol.scand. 1973, 81, 621-626. (med Hellum, K.B.).

47. Wert der transtrachealen Aspiration bei Infektionen der unteren Luftwege.
Infection 1973, 1, 137-143. (med Schreiner, A., Digranes, A. og Myking, O.).

48. Therapy of infections with parenteral cephalexin.
Chemotherapy 1973, 19, 215-220. (med Schreiner, A., Hamre, E. og Digranes, A.).

49. Enhanced susceptibility to infection. Disorders of phagocyte function.
Spectrum International 1974, 17, 41-47.

50. Behandling av sepsis.
T.norske Lægeforen. 1974, 94, 578-580.

51. Isoleringsproblem på sykehus. Behov og teknikk.
Sykepleien 1974, 60, 16-19.

52. Influence of phenylbutazone on the phagocytic and bactericidal activities of neutrophil granulocytes.
Acta path.microbiol.scand. 1974, 82, 258-262.

53. Antibacterial therapy of septicaemia. I Cephalosporins. Dimensions and future.
Excerpta Medica Amsterdam 1974, pp. 124-128.

54. Therapy of infections with oral cephalexin.
Chemotherapy 1974, 20, 315-320. (med Schreiner, A., Kalager, T. og Digranes, A.).

55. Nye cefalosporiner.
T.norske Lægeforen. 1974, 94, 2099-2100.

56. Infectious complications in patients with combined immunodeficiency diseases receiving bone marrow transplants.
Scand.J.Infect.Dis. 1974, 6, 223-231. (med Matsen, J.M., Biggar, W.D. Park, B.H., Niosi, P.N. og Good, R.A.).

57. Spredning av Staphylococcus aureus på sykehus.
J.R^3-symposium, Nordic Association for Contamination Control.
University of Oslo Congress Service 1974, VII, pp.1-8.

58. N.B.T. test in pulmonary embolism and bacterial pneumonia.
Lancet 1974, II, 1575-1576. (med Hellum, K.B.).

59. Gentamicin therapy of Gram-negative bacillary septicaemia. I Progress in chemotherapy.
Proceedings of the 8th international congress of chemotherapy, Athens 1974, II, 494-500.

60. Katastrofemedisin. Infeksjoner.
T.norske Lægeforen. 1975, 95, 535-538. (med Madsen, S.T.).

61. Nyreskade ved cefalotin-gentamycin behandling.
T.norske Lægeforen. 1975, 95, 831-832. (med Laake, H.).

62. Neutrophil granulocyte function in the early diagnosis of acute myelomonocytic and myeloblastic leukaemia.
Acta med.scand. 1975, 197, 147-151. (med Schreiner, A., Hellum, K.B. og Hamre, E.).

63. Influence of therapeutic concentrations of phenylbutazone on granulocyte function.
Acta path.microbiol.scand. Section B. 1975, 83, 100-102.

64. Spinalvæskeforandringer ved infeksjoner i sentralnervesystemet.
T.norske Lægeforen. 1975, 95, 1472-1476.

65. Neutrophil dysfunction and granulomatosis in the preleukemic state.
Scand.J.Infect.Dis. 1976, 8, 53-55. (med Schreiner, A.).

66. Anaerobe infeksjoner I og II.
T.norske Lægeforen. 1976, 96, 249-252, 378-379. (med Schreiner, A.).

67. Acute disseminated phycomycosis in a patient with impaired neutrophil granulocyte function.
Acta path.microbiol.scand. Section C. 1976, 84, 93-99. (med Bruun, J.N., Hamre, E., Janssen, C.J., jr., Thunold, S. og Eide, J.).

68. Influence of antibodies and thermolabile serum factors on the bactericidal activity of human neutrophil granulocytes.
Acta path.microbiol.scand. Section C. 1976, 84, 112-118. (med Christie, K.E., Larsen, B. og Tønder, O.).

69. Influence of IgG, $F(ab')_2$ and IgM on the phagocytic and bactericidal activities of human neutrophil granulocytes.
Acta path.microbiol.scand. Section C. 1976, 84, 119-123. (med Christie, K.E., Larsen, B., Grov, A. og Tønder, O.).

70. Disorders of phagocyte function.

Nordic Symposium on Immunological Maturation. Turku 1975.
Abstract : Scand.J.Immunol. 1976, 5, 450-451.

71. Akutt bakteriell meningitt.

Folia chemotherapeutica "Roche". F.Hoffmann-La Roche & Co. AG, Basel, Sveits 1976.

72. Elektronisk databehandling i overvåking av sykehusinfeksjoner.

T.norske Lægeforen. 1976, 96, 1119-1121. (med Digranes,A., Bernhardsen,S., Glück,E. og Bruun,J.N.).

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Scand.J.Immunol. 1976, 5, 917-924. (med Haneberg,B., Frøland,S.S., Finne,P.H., Bakke,T., Thunold,S., Moe,P.J., Tønder,O., Solheim,B.G. og Dalen,A.).

74. Systolic time intervals in cardiac tamponade.

Acta med.scand. 1976, 200, 465-467. (med Brubakk,O., Kalager,T., Følling,M. og Overå,O.).

75. Influence of phenylbutazone on leukocyte glucose metabolism and function.

J.Reticuloendothel.Soc. 1976, 20, 447-455. (med Kjøsen,B. og Bassøe,H.H.).

76. Pharmacokinetics of cephalosporins.

I Symposium om parenteral intensivterapi med antibiotika. Astra Läkemedel AB, Stockholm, 1976, pp. 53-62. Bröderna Ekstrands Tryckeri AB, Lund 1977.

77. Infectious complications in patients with neoplastic disease and impaired immune response.

I Symposium om intensivterapi med antibiotika. Astra Läkemedel AB, Stockholm, 1976, pp. 281-291. Bröderna Ekstrands Tryckeri AB, Lund 1977.

78. Granulocyte function in bacterial infections in man.
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79. Indikasjoner for antibiotikaprofylakse.
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80. Isoleringstiltak på sykehus.
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81. Doxycyklin (Vibramycin "Pfizer").
T.norske Lægeforen. 1977, 97, 1459-1460 (med Laake, H. og Midtvedt, T.).

82. Antibiotika - kjemoterapeutika. Legemidlene som revolusjonerte behandlingen av infeksjonssykdommene.
"Norges Røde Kors Legebok". pp.219-231. Hermes forlag A/S, Oslo 1977.

83. Influence of hydrocortisone on granulocyte function and metabolism.
Acta path.microbiol.scand. Section C. 1977, 85, 284-288 (med Christie, K.E. og Kjøsen, B.)

84. Human leukocyte migration : Studies with an improved skin window technique.
Acta path.microbiol.scand. Section C. 1977, 85, 413-423 (med Hellum, K.B.).

85. Endocarditis caused by Pasteurella multocida.
Scand.J.Infect.Dis. 1977, 9, 247-248 (med Lehmann, V., Knutsen, S.B., Ragnhildstveit, E. og Skagseth, E.).

86. Pivmecillinam treatment of chronic urinary tract infections.
Infection. Til trykking (med Kalager, T., Bøe, E., Digranes, A. og Høisæther, P.).

87. Infeksjonssykdommer og infeksjonsforsvar.
Forskningsnytt. Norges almenvitenskapelige forskningsråd. Til trykking.

88. Protection of phagocytized bacteria against antimicrobial agents.
I Symposium on tissue penetration of antibiotics. Astra Läkemedel AB, Stockholm 1977. Til trykking (med Hellum, K.B.).

89. Nedsatt resistens mot infeksjoner. Mekanismer.
I Norsk Garamycin-symposium (Schering Corp.), Ustaoset 1977. Universitetsforlaget, Oslo. Til trykking.

90. Behandling av sepsis.
T.norske Lægeforen. Til trykking.

91. Influence of phenylbutazone on leukocyte chemiluminescence and function.
Infect.Immun. Til trykking (med Craig, A. og Hill, H.R.).

92. Effect of antibiotics on the bactericidal activity of human leukocytes.
Infection. Til trykking.

Inndeling av publikasjonene :

1. Vitenskapelige arbeider : Nr. 1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 15, 16, 17, 18, 19, 20, 21, 22, 25, 28, 29, 30, 31, 32, 33, 37, 39, 41, 42, 46, 47, 48, 52, 53, 54, 56, 57, 59, 62, 63, 65, 67, 68, 69, 72, 73, 74, 75, 76, 78, 83, 84, 85, 86, 88, 91, 92. (Scientific)

2. Oversiktsartikler : Nr. 11, 14, 23, 24, 26, 27, 34, 35, 36, 38, 45, 49, 50, 51, 55, 60, 61, 64, 66, 70, 71, 77, 79, 80, 81, 89, 90. (Reviews)

3. "Letters to the editor" : Nr. 12, 40, 43, 44, 58.

4. Populærvitenskapelige arbeider : Nr. 3, 82, 87. (Popular)

Paul Petersson Konstruktionsbyrå AB

DAVID SODERGREN

CURRICULUM VITAE

for

David Södergren

BORN:	May 19, 1922
NATIONALITY:	Swedish
SOCIAL STATUS:	Not married
PRESENT EMPLOYMENT:	Paul Petersson Konstruktionsbyrå AB Consulting Engineers Managing director
EDUCATION:	Graduated 1945 from the Stockholm College of Technology. Degree: Electrical Engineer. Various courses in english, german, mathematics, chemistry. Studies at the Royal Institute of Technology, Dep. for Advanced physics, 1947-1950. Graduated 1952 from the Royal Institute of Technology, Stockholm. Degree: M.Sc. Mechanical Engineering. Various postgraduate courses and participant of conferences in the field of hospital hygiene, thermal comfort, HVAC Building Services.
MISC.:	Member of the Swedish Association of Consulting Engineers. Member of the HVAC-Board of the Swedish Association of Consulting Engineers. Member of the Swedish Association of Heating, Ventilating and Air-Conditioning Engineers. Member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers. Member of FIDIC - Federation Internationale des Ingenieurs Conseils. Member of the Swedish Association of Engineers and Architects. Fellow of the Committee of Industrialized Building Research; Swedish Council for Building Research. Fellow of the Committee for Prevention of Transmission of Infectious Matter within Hospitals; Institute for Organization of National Medical Services.

Member of the Board of Education at the Swedish Association of Heating, Ventilating and Air-Conditioning Engineers.

Fellow of the Association of Environmental Technology.

EMPLOYMENTS:

1945 Swedish SF-Company - marketing of Air-Conditioning Plants.

1946 Swedish Research Institute for National Defence - research and measurements in the field of advanced physics.

1950 AB Atomenergi (National Nuclear Energy Ltd) - design of laboratory equipment.

1951 American Air Filter Co, Kentucky, USA - "exchange student".

1952 Ingenjörsfirman Tewe AB, Stockholm - design and marketing of Air-Conditioning Plants, design of fans, filters, etc.

1954 Swedish SF-Company, Montreal, Canada - design and marketing of Air-Conditioning and Energy Recovery-equipment for the paper-mill industry.

1956 Swedish SF-Company, Stockholm - world-wide marketing of Air-Conditioning equipment.

1957 Kungl. Vattenfallsstyrelsen (National Swedish Power Board) - investigations and analyses of investment- and running-costs for electrical power stations including comparisons between conventional and nuclear power stations. Member of the board of design for the Marviken Nuclear Power Station.

1964 Paul Petersson Konstruktionsbyrå AB, Stockholm - design of HVAC-plants for hospitals:
Uppsala Region Hospital
Nyköping Central Hospital
Växjö Central Hospital
Falu Central Hospital
Mora Hospital
Enskededalen Central Hospital
Sundsvall Central Hospital

1971 Managing Director, Paul Petersson Konstruktionsbyrå AB - design of HVAC-plants:

Vitrum Pharmaceuticals Ltd - design of HVAC-plants for laboratories and production-buildings

War-hospitals for the National Defence - Fortifikationsförvaltningen.

Falu Central Hospital
Mora Hospital

Office-buildings for the Postal Banking Services, National Railways, and others.

BIBLIOGRAPHY:

Södergren D and Boström T, 1971 Ventilating with the "Exhaust Air Window". (ASHRAE Journal, No. 4 Vol. 13) New York.

Södergren D, and Boström T, 1971 Ventilation and Temperature Control System with "Exhaust Air Windows" and Electric Heaters in Supply Air Diffusers (Proceedings from 5th International Congress for Heating, Ventilating and Air-Conditioning, Polyteknisk Förlag) Copenhagen.

Södergren D, and Isfält E, 1974 Restrainer-house for sunenergy with "Heating and ventilationsystem by storing of heating of sunenery in the buildingframework" (VVS Journal, No.4).

Södergren D, and Boström T, "The vent-window a principle for the thermal environment" (B.S.E. March 1973).

Södergren D, 1975."The Energy Saving Solation in Industrial Buildings. (Proceedings from the ASHRAE congress How to Save Energy in Existing Buildings) London 1975.

Södergren D, Sandberg L and Boström T 1976 Sundsvall Hospital-Heating and air-conditioning adapted to present demand of economy, comfort and hygiene. VVS vol. 47, Febr. 1976.

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Södergren D, Backman L-E and Lassen C, 1977. The Energy Saving project - Märsta Hospital. VVS vol. 48, Dec. 1977.

C U R R I C U L U M V I T A E

Name: John August Ulrich Social Security No.: 475-10-5028

Birth: May 15, 1915 - St. Paul, Minnesota

Marital Status: Married, June 8, 1940

Wife: Margaret M. Nash Children: Jean Anne, John Joseph, Robert Charles, Karl James, Mary Ellen, Lenore Alice

Home Address: 9416 Gutierrez Road, NE
Albuquerque, New Mexico 87111

Business Address:
Department of Microbiology
School of Medicine
The University of New Mexico
Albuquerque, New Mexico 87131

Scholastic Record:

Cretin High School, St. Paul, Minnesota, 1933

B.S. Major: General Science; Minor: Teaching
St. Thomas College, St. Paul, Minnesota 1938

Ph.D. Major: Bacteriology; Minor: Physiological Chemistry
University of Minnesota, Minneapolis 1947

Courses in Medical Mycology and Tuberculosis
Communicable Disease Center, Atlanta 1949

Research Grants

AM - 02011 Amino-Aciduria in Pancreatitis 9-1-59 to 8-31-63 $33,000

Principal Investigator: John A. Ulrich
Co-investigator: John Gross

AM - 07497 Antigens of Histoplasma capsulatum 1-1-62 to 12-31-65 $45,000

Principal Investigator: Harold Markowitz
Co-investigator: John A. Ulrich

PH - 108-65-26 Recirculation of Air in Operating Rooms 9-1-64 to 8-31-67 $87,000

Principal Investigator: John A. Ulrich

PH - 108-66-307 Microbial Contamination and Care of Tonometers $ 1,400 June, 1966

Principal Investigator: John A. Ulrich

Professional Experience:

1938-41	Instructor, De La Salle High School, Chemistry, Biology and General Science,
1941-45	Research Assistant, Teaching Assistant and Instructor in Bacteriology, University of Minnesota
1945-49	Research Assistant, Hormel Institute, University of Minnesota, Austin, Minnesota
1949- to present	Consultant in Microbiology and Biochemistry, Mayo Clinic,
1949-55	Instructor in Mayo Foundation, University of Minnesota
1955-66	Assistant Professor, Mayo Foundation, University of Minnesota
1966-69	Associate Professor, Mayo Graduate School of Medicine
1966-69	Associate Professor, University of Minnesota
1966 to present	Professor, School of Medicine, The University of New Mexico

Civic

1. Chairman: Camping Committee -- Zumbro Valley District. Boy Scouts of America, 1951-53.

2. Chairman: Zumbro Valley Executive Board B.S.A. 1953-55.

3. Chairman: Camping Committee, Gamehaven Area, B.S.A., 1956-62.

4. Member, Gamehaven Executive Board, B.S.A., 1957 - 1969.

5. Precinct Chairman, Democratic Farmer Labor Party 5th Ward. 2nd Precinct, Rochester, Minnesota, 1964 to 1969.

6. Member, Democratic Farmer Labor Olmsted County Committee, 1964 to 1969.

Decorations and Awards

Silver Beaver, Boy Scouts of America, 1962, Bishops Medal, Winona Diocese, 1962.

Other

President: Zumbro Valley Toastmasters Club 1962-63.

President: Rochester Deanery, Winona Diocese 1961-63

Chairman: Religious Activities, Winona Council of Catholic Men, 1963-69

Noteworthy Special Work

Research in the following areas:

1. Food preservation 1945-47
2. Survival of Microorganisms at Low Temperatures 1945 to present
3. Urinary Amino Acid Excretions in a Variety of Disease States 1949-64
4. Research in Clinical Microbiology 1949 to present
5. Post-operative Wound Infections 1960 to present
6. Bacterial Skin Populations 1960 to present

Honors Received:

1945	Sigma Xi
1945	Gamma Alpha
1961	Fellow - American Academy of Microbiology
1962	Diplomate of the Board - American Board of Medical Microbiology
1962-63	Vice President - North Central Branch, American Society for Microbiology
1963-64	President - North Central Branch, American Society for Microbiology
1963	Visiting Professor - University of Texas Medical School, Galveston April
1964	Convener - Synthetic Antimicrobials, Fourth Interscience Conference on Antimicrobial Agents and Chemotherapy - American Society for Microbiology, NY, October 28
1972	Chairman - Seminar on "Role of the Environmental and Infection Control in Health Facilities" - February 15-17, Albuquerque, NM

Consultancies:

1943-44	Bacteriology of War Wounds - Under Dr. W.B. Clark, University of Minnesota
1944-45	Epidemiology of Polio - Under Dr. C.A. Evans, University of Minnesota
1945	Consultant for Economic Laboratories, St. Paul, Minnesota on Germicidal Detergents
1947	Consultant for Hormel Packing Plant, Austin, Minnesota - Directing Sanitation Studies and Training Personnel
1956-59	Member - Microbiology Study Section, National Institutes of Health
1959-61	Member - Bacteriology and Mycology, Study Section, National Institutes of Health
1961-64	Chairman - Bacteriology and Mycology Study Section, National Institutes of Health
1961-69	Member - Executive Board for Certification of Public Health and Medical Laboratory Mycology, American Board of Microbiology
1962	Member - Eli Lilly Award Committee for Bacteriology
1962 to present	Member - American Public Health Association, Hospital and Facilities Committees
1963	Member - Planning Committee, National Conference on Institutionally Acquired Infections, University of Minnesota
1963 to present	Member - American Public Health Association, Laboratory Section Committee on Microbial Contamination of Surfaces
1965-68	Member - Space Craft Sterilization Advisory Committee, AIBS - NASA
1966-69	Chairman - Executive Board for Certification in Public Health and Medical Laboratory Mycology, American Board of Microbiology
1966 to present	Consultant - AIBS - NASA, Planetary Quarantine Advisory Committee
1967-70	Member - Communicable Disease Prevention Study Section, Communicable Disease Center
1968-69	Chairman - Communicable Disease Prevention Study Section, Communicable Disease Center

Consultancies: (Continued)

1969 to present	Member - AIBS Experiment Survey Program Ad Hoc Proposal Study Group
1970	Consultant - Veterans Administration Hospital, Albuquerque, NM
1971	Sandia Laboratories, Albuquerque, NM
1972	Midwest Research Institute, Kansas City, MO, February 11-12
1972-74	Barrier Technics in Control of Post-Surgical Infections with Midwest Research Institute, Kansas City, MO
1974	Interscience Conference on Antimicrobial Agents and Chemotherapy, San Francisco - September 12-13
1974 to present	Associate Councilor - New Mexico Branch of the American Society for Microbiology
1974	Committee on Surface Sampling, American Public Health Association

Professional Activities: (meetings attended and lectures presented)

1972	University of Massachusetts Seminar, New York City, NY - September 7-8
1972	International Symposium on Anaerobic Bacteria and Anaerobic Infections at Atlanta, GA - November 27-29
1973	Project Site Visit - UCLA, Dr. Miller - January 1-24
1973	Association of Operating Room Nurses, Chicago - March 19-21
1973	Bernalillo County Medical Center - Medicine, Enterics - March 30
1973	Veterans Administration Hospital - Pathology - Mycobacteria - May 24
1973	Veterans Administration Hospital - Pathology - Antibiotic Testing - May 29
1973	Veterans Administration Hospital - Pathology - Anaerobes, December 11
1974	American Society for Microbiology - Tucson, AZ - December 4-6
1975	American Society for Microbiology - New York - April 27- May 2

PUBLICATIONS

1. Ulrich, John A.: New Indicators to Replace Litmus in Milk. Reprinted from Science, 99:352, No. 2574, April 28, 1944.

2. Ulrich, John A.: Microbiological Studies on Canned Bacon. Annual Report of the Hormel Institute 1945-46, pp. 26-33.

3. Ulrich, John A. and Halvorson, H.O.: Microbiological Studies on Canned Bacon. Annual Report of the Hormel Institute 1946-47, pp. 23-26.

4. Ulrich, John A., Tsuchuja, H.M. and Halvorson, H.O.: The Microbiology and Chemistry of Canned Bacon. Journal of Bacteriology 53:377, 1947.

5. Ulrich, John A. and Halvorson, H.O.: Investigation of Changes in Foods. During Storage in the Frozen Condition. Annual Report of the Hormel Institute 1946-47, pp. 44-46.

6. Ulrich, John A.: Microbiological Studies on Canned Bacon. Annual Report of the Hormel Institute 1947-48, pp. 25-29.

7. Ulrich, John A. and Halvorson, H.O.: Investigation of Changes in Foods During Storage in the Frozen Condition. Annual Report of the Hormel Institute 1947-48, pp. 48-52.

8. Ulrich, John A.: Studies of Sliced Canned Bacon. National Provisioner, August 14, 1948, p. 19.

9. Ulrich, John A. and Larsen, Arlene M.: A Single Solution Indicator for Anaerobiosis. Journal of Bacteriology. 56: No. 3, September, 1948.

10. Ulrich, John A.: Tests on Bacon Point Way to Keep it Fresh in Cans. Food Industries 29:79, 1949.

11. Ulrich, John A. and Halvorson, H.O.: Chemical and Microbial Studies on Sliced Canned Bacon. Advances in Food Research, Vol. 3, 1951.

12. Ulrich, John A. and Fitzpatrick, Thomas B.: Reversible Inhibition of Growth of Microsporum audouini with Neopyrithiamine. Proceedings of the Society for Experimental Biology and Medicine, 76:346-349, 1951.

13. Weber, Walter E. and Ulrich, John A.: Kerion Caused by Trichophyton Rubrum A.M.A. Archives of Dermatology and Syphilology, 66:624-626, November, 1952.

14. Ulrich, John A. and Needham, Gerald M.: Differentiation of Alcaligenes Faecalis from Brucella Bronchiseptious by Biochemical and Nutritional Methods. Journal of Bacteriology, Vol. 65, No. 2, February, 1953.

15. Weed, Lyle A., Needham, Gerald M. and Ulrich, John A.: Importance of Bacteriologic Study in Diagnosis of Pulmonary Disease. The Medical Clinics of North America, 38:1219-1226, No. 4, July, 1954.

16. Ulrich, John A.: Urinary Excretion of Amino Acids by Human Subjects on Unrestricted Diets. Proceedings of the Staff Meetings of the Mayo Clinic, Vol. 29, No. 8, April 21, 1954.

17. Salassa, Robert M., Power, Marschelle H., Ulrich, John A. and Hayles, Alvin D.: Observations on the Metabolic Effects of Vitamin D in Vanconi's Syndrome, Proceedings of the Staff Meetings of the Mayo Clinic, 29:623-631, No. 8, April 21, 1954.

18. Perry, Harold O. and Ulrich, John A.: Laboratory Studies on Endomycin. With Special Reference to its Antigungal Effect Against Candida Albicans, The Journal of Investigative Dermatology, Vol. 24, No. 6, June, 1955.

19. Getz, Kaare, Skillern, Scott D. and Ulrich, John A.: Studies on "Mosaic Fungus" The Journal of Investigative Dermatology, Vol. 25, No. 1, July, 1955.

20. Geraci, Joseph E., Dry, Thomas J., Ulrich, John A., Weed, Lyle A., MacCarty, Collins, S., Sayre, George P.: Experiences with 2-Hydroxystilbamidine in Systemic Sporotrichosis. A.M.A. Archives of Internal Medicine, 96:478-489, October, 1955.

21. Ulrich, John A.: Media and Methods for the Isolation and Identification of Pathogenic Fungi, Bacteriological Proceedings, 1956, p. 87.

22. Gross, John B., Comfort, Mandred W. and Ulrich, John A.: Abnormalities of Serum and Urinary Amino Acids in Hereditary and Non-Hereditary Pancreatitis, Transactions of the Association of American Physicians, 60:127, 1957.

23. Gross, John B., Comfort, Mandred W., Ulrich, John A.: The Current Status of Hereditary Pancreatitis, Minnesota Medicine 41:78-82, February, 1958.

24. Eelkema, H. Harrison, Scanlon, Paul W., Colby, Malcolm Y. and Ulrich, John A.: Thrush Complicating Radiotherapy of the Mouth and Neck, Radiology, 72:26-29, No. 1, January, 1959.

25. Martin, William J., Nichols, Donald R., Svien, Hendrick J. and Ulrich, John A.: Cryptococcosis. Further Observations and Experiences with Amphotericin B. A.M.A. Archives of Internal Medicine, 104:4-14, July, 1959.

26. Stickler, Gunnar B., Hayles, Alvin B., Power, Marschelle H1, and Ulrich, John A.: Renal Tubular Dysfunction Complicating the Nephrotic Syndrome, Pediatrics, 26:75-85, No. 1, July, 1960.

27. Millichap, J. Gordon and Ulrich, John A.: Abnormal Urinary Excretion of Amino Acids in Children with Petit Mal Epilepsy. Preliminary Communication, Proceedings of the Staff Meetings of the Mayo Clinic, 37:307-310, No. 11, May 23, 1962

28. Gross, J.B., Gambill, E.E., Ulrich, John A.: Hereditary Pancreatitis. Description of a Fifth Kindred and Summary of Clinical Features, American Journal of Medicine, 33:358-364, No. 33, September, 1962.

29. Stickler, G.B., Rosevear, John W. and Ulrich, John A.: Renal Tubular Dysfunction Complicating the Nephrotic Syndrome. The Disturbance in Calcium and Phosphorus Metabolism, Proceedings of the Staff Meetings of the Mayo Clinic 37:376-387, No. 14, July 4, 1962.

30. Karlson, A.G. and Ulrich, John A.: A Medium for Testing the Utilization of Substances by Various Mycobacteria, American Review of Respiratory Diseases, Vol. 86, No. 2, August, 1962.

31. Gross, J.B., Ulrich, John A. and Maher, Frank T.: Further Observations on the Hereditary Form of Pancreatitis. Reprinted from Ciba Foundation Symposium on the Exocrine Pancreas, 1962, pp. 278-305 (edited by A.V.S. deReuck and Margaret P. Cameron). Published by J. & A. Churchill Ltd. 104 Gloucester Place, London, W. I.

32. Ulrich, John A.: Isolation and Identification, Proceedings National Conference on Institutionally Acquired Infections. Public Health Service Publication #1188, pp. 80-83, 1964.

33. Gross, J.B., Ulrich, John A., Jones, J.D. and Maher, F.T.: Endogenous Renal Clearance of 12 Individual Amino Acids in Four Apparently Healthy Subjects and in Four Aminoaciduria. Persons of a Kindred with Hereditary Pancreatitis, Journal of Laboratory and Clinical Medicine, 63:933-944.

34. Gross, J.B., Ulrich, John A. and Jones, J.D.: Urinary Excretion of Amino Acids in a Kindred with Hereditary Pancreatitis and Aminoacidurea. Gastroenterology 47:41-48, 1964.

35. Ulrich, J.A.: Technics of Skin Sampling for Microbial Contaminants Health Laboratory Science, APHA, Health and Laboratory Science I, 133-136, 1964. (Reprinted in Hospital Topics).

36. Ulrich, John A.: Dynamics of Bacterial Skin Populations. Published in Skin Bacteria and Their Role in Infection, Blakiston, New York, 1965.

37. Ulrich, John A.: Observations of Fungal Growth In Vitro and In Vivo, Journal of Leprosy 33 (Part 2):477-484, 1965.

38. Vrabec, D.P., Cody, D.T.R. and Ulrich, J.A.: A Study of the Relative Concentrations of Antibiotics in the Blood, Spinal Fluid and Perilymph in Animals. Annals Otology, Rhinology and Laryngology 74:688-706, 1965.

39. Wellman, William E. and Ulrich, J.A.: A Bacterial Survey of Two Areas in One Hospital by the Settling Plate Method, Mayo Clinic Proceedings, 40:708-713, No. 9, 1965.

40. Ulrich, John A.: Skin Carriage of Bacteria in the Human, Symposium of the National Conference on Spacecraft Sterilization Technology, SP 108 pp. 87-95, Washington, D.C., NASA Scientific and Technical Information Division, 1966.

41. Weigand, S.E., Ulrich, J.A., and Winkelmann, R.K.: Diagnosis of Superficial Pathogenic Fungi: Use of Ink Blue Agar Method, Proceedings- Mayo Clinic 43:795-802, 1968.

42. Ulrich, J.A.: Microbial Flora of Human Skin, McGraw-Hill Yearbook of Science and Technology, 1969, New York.

43. Goldman, S., Lipscomb, R.R., Ulrich, J.A.: Geotrichum Tumefaction of the Hand, Journal of Bone and Joint Surgery 51:587-590, 1969.

44. Hermans, P.E., Ulrich, J.A. and Markowitz, H.: Chronic Microcutaneous Candidasis as a Surface Expression of Deep Seated Abnormalities: With Report of a Syndrome of Superficial Candidiasis, Absence of Delayed Hypersensitivity and Amino Aciduria, American Journal of Medicine, 47: 503-519, 1969.

45. Karlson, A.G. and Ulrich, J.A.: Stability of Rifampin in DiMethylsulfoxide, American Review of Respiratory Diseases, Applied Microbiology 18: 692-3, 1966.

46. Martin, J.R. and Ulrich, J.A.: Bacterial Filter for an Anesthesia Circuit, Anesthesia and Analgesia 48: 944-946, 1969.

47. Ulrich, J.A. -- Co-editor: Mycology Section of Manual of Clinical Microbiology, Blair, Truant, Lennette; Williams and Wilkins, 1970.

48. Ulrich, J.A.: Office Microbiology - Abstract in Antibiotic and Infection, University of Iowa College of Medicine, 1971, pp. 82a and b.

49. Ulrich, J.A.: Microbiology of Surgery Suites, Clean Room Technology in Surgery Suites, 1971, pp. 11-31. Midwest Research Institute Reprint #1064.

50. Espinoza, Herman, M.D., Palmer, Darwin L., M.D., Kisch, Alexander, M.D., Ulrich, John, Ph.D., Eberle, Betty, Ph.D., and Reed, William P., M.D., Immunological Response to Colonization and Infection of the Respiratory Tract. A study following tracheostomy, Journal of Thoracic and Cardiovascular Surgery, 1974, 68: No. 3, pp. 432-439.

51. Winkelmann, Richard K. Jones, James D. and Ulrich, John A., Urinary Amino Acid Excretion in Patients with Scleroderma, May Clin. Proc. 46: 114-118, February, 1971.

52. Ulrich, John A.: The Facultative Aerobic Microbial Flora of Normal Human Skin, Development in Industrial Microbiology, 14: 137-143, 1973.

53. Duncan, J. and Ulrich, J.A.: The Assimilation of Hydrocarbons by Pseudomonas Strains Isolated from Human Clinical Specimens, Applied Microbiology, 26: 894-898, December, 1973.

54. Espinoza, H., Palmer, D.L. Kisch, A.L., Ulrich, J.A., Eberle, B.: Clinical and Immunologic Response to Bacteria Isolated from Tracheal Secretions Following Tracheostomy. The Journal of Thoracic and Cardiovascular Surgery 68: No. 3, 432-439, 1974

55. Ulrich, J.A., Cribbs, W. and Michaelsen, G.S.: Recirculation of Air in Operating Rooms, Ashrae Journal, August, 1974.

56. Smith, Edgar B., Powell, Ralph F., Graham, Jack L., and Ulrich, John A. Topical Undecylenic Acid in Tinea Pedis: A New Look, International Journal of Dermatology, 16: 52-56, January/February, 1977.

57. Smith, Edgar B., Graham, Jack L., and Ulrich, John A., Topical Clotrimazole in Tinea Pedis, Southern Medical Journal, 70: 47-48, January 1977.

58. Ulrich, John A., Cribbs, B.E., and Michaelsen, G.S., Recirculation of air in operating rooms, Medical Instrumentation, 10: 282-286, December 1976.

Appendix C: Conference Participants

Mr. Richard G. Bond
Professor
Environmental Health
University of Minnesota
Minneapolis, Minnesota 55455

* *"Professor Bond has initiated many of our training and research efforts at the University as associated with the institutional environment."*

Mr. C. Luverne Carlson
Assistant Vice President
Support Services and Operations
University of Minnesota
Minneapolis, Minnesota 55455

"Mr. Carlson serves as the energy coordinator for the University."

Mr. Robert W. Gish, P.E.
Director of Engineering
Smiley-Glotter Associates, Inc.
Minneapolis, Minnesota 55403

"Mr. Gish has extensive experience in all design phases of educational, institutional and health care fields."

Mr. Marvin Gough
Staff Associate
Division of Health Delivery Systems
American Hospital Association
Chicago, Illinois 60611

"Mr. Gough has primary responsibility for the American Hospital Association's energy conservation programs. He works closely with the American Society of Hospital Engineers bringing us a link with hospital engineers all around the country."

Mr. Edward Howard
Assistant Director
Bureau of Environmental & Structural Services
New York Health Department
Albany, New York 12237

"Mr. Howard has many years of regulatory experience in aspects of hospital design and operation."

Mr. John Janssen
Senior Staff Engineer
Energy Resources Center
Honeywell, Inc.
Minneapolis, Minnesota 55413

"Mr. Janssen has been involved with studies on the effect of thermal radiation and comfort. More recently he has been involved with measurement of buildings for environmental parameters, particularly those related to infiltration and ventilation."

Mr. Donald T. Johnson, P.E.
Energy Conservation Program Coordinator
State Department of Administration
St. Paul, Minnesota 55155

"Mr. Johnson is responsibile for surveying all state-owned buildings. He has a hospital background and was the director of facilities for a large hospital complex here in the Metropolitan area."

*These comments are extracted from opening remarks given by Dr. Roger L.DeRoos.

Mr. Hans P. Larsen
Chief of Engineering Services
Health Facilities Division
Minnesota Department of Health
Minneapolis, Minnesota 55440

"Since the ultimate objective of this project is to determine and to examine hospital design parameters it is appropriate that Mr. Larsen is in attendance."

Mr. E.B. Merz
Assistant Supervising Engineer
Engineering and Construction Division
Physical Planning Office
University of Minnesota
Minneapolis, Minnesota 55455

"Mr. Merz is primarily responsible for review and design of heating, ventilating and air conditioning systems."

Mr. Robert Reid
Principal Engineer
Physical Plant Administration
University of Minnesota
Minneapolis, Minnesota 55455

"Mr. Reid who represents Mr. Warren Soderberg, director of the University's Physical Plant, is particularly involved with a study of the Grid Connected Integrators Community Energy System...most specifically with the hospital solid waste portion of that study."

Mr. Dick K. Riemensnider
Solar Energy Consultant
U.S. Department of Health, Education, and Welfare
Public Health Service
Hyattsville, Maryland 20782

"Mr. Riemensnider was a consultant with the Hill Burton Program in matters relating to environmental health. He is active in solar energy demonstration projects in relation to health care facilities."

Dr. John Swope, M.D.
Bureau of Medicine and Surgery
Department of the Navy
Washington, DC 20372

"Dr. Swope is concerned with the Bureau's hospital design and construction program and brings us the perspective of an M.D. with specific orientation to the design of facilities."

Dr. Isaac Turiel
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

"Dr. Turiel is here on behalf of LBL's principal investigator for this project, Dr. Craig D. Hollowell. He is the author of a textbook, "Physics and the Environment of Man," which discusses conventional and alternative methods of energy conversion in their environmental public health and climatic impacts."

Dr. Donald Vesley
Professor
Environmental Health
University of Minnesota
Minneapolis, Minnesota 55455

"Dr. Vesley is Director of the Institutional Environmental Health Training efforts at the University."

Dr. James Woods
Associate Professor
Engineering Research Institute
Iowa State University of Science and Technology
Ames, Iowa 50010

"Dr. Woods has a strong interest in ventilation and thermal comfort and is presently principal investigator for a nationally-sponsored project relating to ventilation requirements in operating rooms.

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TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720