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This new edition of HVAC Design Manual for Hospitals and Clinics provides in-depth, up-to-date design recommendations based on best practices from consulting and hospital engineers with decades of experience in the design, construction, and operation of health care facilities. It presents solutions that are proven, cost effective, and reliable--solutions that provide low maintenance cost and high reliability, with a focus on presenting what's different about health care HVAC Features: Essential guidance onenvironmental comfortinfection controlenergy conservationlife safetyoperation and maintenancedisaster planning strategies''best practices'' recommendations on temperature, humidity, air exchange, and pressure requirements for various types of rooms found in hospitals Benefit to the Customer: Contains the collected wisdom of many experts' years of experienceAn invaluable resource for ensuring that vital issues specific to health care are addressedASHRAE, founded in 1894, is an international organization of some 50,000 persons. ASHRAE fulfills its mission of advancing heating, ventilation, air conditioning, and refrigeration to serve humanity and promote a sustainable world through research, standards writing, publishing, and continuing education. The ASHRAE Handbooks are the design standard for control of built environments with volumes on Systems and Equipment, HVAC Applications, Refrigeration and Fundamentals. Each is updated every four years. In addition to publishing design guidance for engineers, architects, and facility managers, we also publish a series of texts for classroom use. Some of the areas we publish in include: -Energy Modeling and Auditing -High Performance Building Design -Psychrometrics -Indoor Air Quality and Environmental Quality -Data Center Energy Efficiency -Noise & Vibration Control -Humidity Control -HVAC for Healthcare Facilities Health care HVAC systems serve facilities in which the population is uniquely vulnerable and exposed to an elevated risk of health, fire, and safety hazard. These heavily regulated, high-stakes facilities undergo continuous maintenance, verification, inspection, and recertification, typically operate 24/7, and are owner occupied for long life. The HVAC systems in health care facilities must be carefully designed to be installed, operated and maintained in coordination with specialized buildings services, including emergency and normal power, plumbing and medical gas systems, automatic transport, fire protections and a myriad of IT systems, all within a limited building envelope. You're Reading a Free Preview Pages 11 to 24 are not shown in this preview. You're Reading a Free Preview Pages 30 to 43 are not shown in this preview. You're Reading a Free Preview Pages 49 to 62 are not shown in this preview. You're Reading a Free Preview Pages 68 to 79 are not shown in this preview. You're Reading a Free Preview Pages 93 to 107 are not shown in this preview. You're Reading a Free Preview Pages 114 to 115 are not shown in this preview. You're Reading a Free Preview Pages 124 to 126 are not shown in this preview. You're Reading a Free Preview Pages 130 to 131 are not shown in this preview. 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Full PDF PackageDownload Full PDF PackageThis PaperA short summary of this paper24 Full PDFs related to this paperDownloadPDF Pack Receive all IIR and refrigeration news in our newsletter : This manual provides those involved in the design, installation, and commissioning of HVAC systems for hospitals with a comprehensive reference source for their work. The text covers environmental comfort, infection control, energy conservation, life safety, and operation and maintenance, providing design strategies known to meet applicable standards and guidelines. It also contains information on disaster planning and provides "best practice" recommendations on temperature, humidity, air exchange, and pressure requirements for various types of rooms found in hospitals. A chapter on terminology begins to define several medical terms for the design engineer. HVAC DESIGN MANUAL FOR HOSPITALS AND CLINICS This publication was prepared under ASHRAE Special Project SP-91 in cooperation with the cognizant ASHRAE group, TC 9.8, Large Building Air-Conditioning Applications. LIST O F C O N T R I B U T O R S F i n a l Voting C o m m i t t e e M e m b e r s Robert Cox, P.E. Farnswortk Group Paul J. DuPont, P.E. DuPont Engineering Douglas Erickson American Society jor Health Care Engineering Kimball Ferguson, P.E. Duke University Health System Milton Goldman, M.D.. RE. Mann Mechanical Co. Jeffrey Hardin, RE. U.S. Army Corps of Engineers Richard D. Hermans, P.E. Center for Energy and Environment Carl N. Lawson Duke University Medical Center John Lewis, P.E. P2S Engineers, Inc. Farhad Memarzadeh, Ph.D., P.E. National Institutes of Health Frank A. Mills, C.Eng. Environmental Design Consultants Ltd., U.K. Vince Mortimer NtOSH Paul T. Ninomura, P.E. Indian Health Service Mary Jane Phillips U.S. Navy Bureau of Medicine and Surgery (Ret.) Anand K. 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Calif James E. Woods, Ph.D., P.E. (Chapter 2) Building Dianostic Research Institute Mark Yankich, P.E. (Chapter 9) Rogers, Lovelock, and Fritz Walter Grondzik, Technical Editor (All Chapters) Florida A&M University M M HVAC DESIGN MANUAL F O R HOSPITALS AND CLINICS H A m e r i c a n Society of H e a t i n g , Refrigerating a n d A i r - C o n d i t i o n i n g E n g i n e e r s , Inc. ISBN 1-931862-26-5 ©2003 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E. Atlanta, GA 30329 www.ashrae.org All rights reserved. Printed in the United States of America Cover design by Tracy Becker. ASHRAE has compiled this publication with care, but ASHRAE has not investigated, and ASHRAE expressly disclaims any duty to investigate, any product, service, process, procedure, design, or the like that may be described herein. The appearance of any technical data or editorial material in this publication does not constitute endorsement, warranty, or guaranty by ASHRAE of any product, service, process, procedure, design, or the like. ASHRAE does not warrant that the information in the publication is free of errors, and ASHRAE does not necessarily agree with any statement or opinion in this publication. The entire risk of the use of any information in this publication is assumed by the user. No part of this book may be reproduced without permission in writing from ASHRAE, except by a reviewer who may quote brief passages or reproduce illustrations in a review with appropriate credit; nor may any part of this book be reproduced, stored in a retrieval system, or transmitted in any way or by any means—electronic, photocopying, recording, or other—without permission in writing from ASHRAE. ASHRAE Staff Special Publications Publishing Services Mildred Geshwiler Editor Barry K u r i a n Manager E r i n S. Howard Assistant Editor Jayne Jackson Production Assistant Christina Helms Assistant Editor Michshelle Phillips Secretary Publisher W. Stephen Comstock DEDICATION This design manual is dedicated to our friend and colleague, John Lewis. While the manual was being prepared, John suffered a stroke. During the final months of its preparation, we missed his engineering insight, his insistence on technical accuracy, and clear and understandable writing. Above all, we missed his humor and friendly presence at our meetings. We look forward to his continuing contribution to health care engineering and HVAC design. The ASHRAE SP 91 Committee is grateful for extraordinary effort by John Lewis in creating this document. CONTENTS FOREWORD xiii CHAPTER 1—INTRODUCTION [illegible] CHAPTER 2—TERMINOLOGY [illegible] CHAPTER 3—FACILITY DESCRIPTIONS [illegible] CHAPTER 4—OVERVIEW OF HEALTH CARE HVAC [illegible] CHAPTER 5—HVAC SYSTEMS [illegible] CHAPTER 6—DESIGN CONSIDERATIONS FOR EXISTING FACILITIES [illegible] CHAPTER 7—COOLING PLANTS [illegible] CHAPTER 8—SPACE AND PROCESS HEATING SYSTEMS [illegible] CHAPTER 9—AIR-HANDLING AND DISTRIBUTION SYSTEMS [illegible] CHAPTER 10—CONTROLS AND INSTRUMENTATION [illegible] CHAPTER 11—SMOKE CONTROL AND LIFE SAFETY [illegible] CHAPTER 12—ROOM DESIGN [illegible] CHAPTER 13—CLINICS AND OTHER HEALTH CARE FACILITIES [illegible] CHAPTER 14—OPERATION AND MAINTENANCE [illegible] CHAPTER 15—COMMISSIONING [illegible] CHAPTER 16—ENERGY EFFICIENT DESIGN AND CONSERVATION OF ENERGY RESOURCES [illegible] APPENDIX A—MANAGING CONSTRUCTION AND RENOVATION TO REDUCE RISK IN HEALTH CARE FACILITIES [illegible] APPENDIX B—DISASTER MANAGEMENT [illegible] APPENDIX C—LOAD CALCULATIONS AND EQUIPMENT HEAT GAINS [illegible] APPENDIX D—INFECTION CONTROL ISSUES [illegible] APPENDIX E—LIFE-CYCLE COST ANALYSIS [illegible] APPENDIX F—VENTILATION STANDARDS AND CURRENT TRENDS [illegible] APPENDIX G—POWER QUALITY ISSUES [illegible] APPENDIX H—SAMPLE CONTROL STRATEGIES [illegible] APPENDIX I—OPERATING ROOM AIR DISTRIBUTION [illegible] REFERENCES [illegible] BIBLIOGRAPHY [illegible] INDEX [illegible] FOREWORD First and foremost, this document is not a standard or a guideline. It is a design manual. It provides design strategies known to meet applicable standards and guidelines, whatever they may be. [illegible] research. Some of this research was conducted by one of the committee members and published by ASHRAE. Dr. Farhad Memarzadeh, from the National Institutes of Health, conducted extensive research on patient room, isolation room, and operating room air distribution. The research used both numerical and experimental techniques. Numerical technique included computational fluid dynamics and particle tracking model. The performance of the numerical approach was successfully verified by comparison with an extensive set of experimental measurements. The patient room findings helped change the ventilation rates in the Guidelines for Health Care Facilities, published by AIA. The operating room results will be incorporated in the next edition of the ASHR.4E Handbook. As discussed in the Design Manual, temperature, humidity, and ventilation play important roles in the survival of airborne microorganisms. Most codes that are applicable to HVAC construction, however, do not currently address HVAC design criteria relevant to the effectiveness of ventilation, temperature, or humidity in controlling airborne microorganisms. The problem appears to be less prevalent in North American jurisdictions but is a real and serious problem in many parts of the world. The intent of this statement is only to point out an existing problem, which must be corrected through other channels. We hope that the Design Manual will be adopted widely and used as a tool for education. We also hope that it will start an open dialog with code officials, the Authority Having Jurisdiction (AHJ), clinicians, and HVAC designers, which will lead to the adoption of reasonable standards. I want to thank ASHRAE for giving me the opportunity and privilege to contribute in a major way to a definitive document associated with one's profession. I also wish to thank two individuals in particular: Mark Lentz,"past chair of ASHRAE TC 9.8 (Large Building Air-Conditioning Applications), who took the lead in starting this project and recruiting me. The other is William Seaton, who, in his position of Manager of Research for ASHRAE, provided us with all of the needed support. I also want to thank ASHRAE and Michael Vaughn, Manager of Research and Technical Services, for continued support and confidence. It has been my privilege to work with a group of highly talented individuals who freely and voluntarily gave their time and incurred expenses to work on this manual. To all of them, I extend a hearty personal and ASHRAE thank you. I have included a list of current committee members and other contributors. During the past four years while this manual was being compiled, several committee members were forced, due to time constraints or health, to relinquish their involvement in this work. I do not want to minimize their contribution because it was very significant. Those contributors who were former committee members are so marked. I thank the SP 91 committee and the many other contributors for their time and hard work. Respectfully submitted, Anand K. Seth, P.E. Chair, SP 91 May 2003 Xlll CHAPTER 1 INTRODUCTION 1.1 PREFACE The design of heating, ventilating, and air-conditioning (HVAC) systems for hospitals, outpatient clinics, and other health care facilities is a specialized field of engineering. The higher filtration requirements for operating rooms and the pressure relationships between adjacent spaces are a few of the many design issues that are especially critical to the proper design and functioning of an HVAC system in a health care facility. Health care facilities have special design criteria. Knowledge of, and insight into, these criteria are needed to develop a design that will satisfy the owner and operators of the facility. Knowledge of regulatory requirements will minimize compliance problems. There are special considerations for the design of operating rooms. The HVAC requirements for operating rooms include regulating temperature and humidity, as well as space pressurization, filtration of the supplied air. allowable recirculation of the air. and the effectiveness of air delivery system options. Health care facilities are environments of controlled hazards. Exposure to aerosolized pharmaceuticals, airborne contagions, and strong cleaning chemicals are examples of these hazards. Building-related illness, especially associated with airborne infectious agents, continues to be a challenge for health care organizations that treat infectious patients and those extremely susceptible to environmental microbes such as Legionella and Aspergillus. This manual will help delineate best practices for design and maintenance to optimize the safety of occupants. A fundamental premise of this manual is that a well-designed HVAC system augments the other facets of the built environment to offer a healing environment;" minimizes the airborne transmission of viruses, bacteria, fungal spores, and other bioaerosols; and minimizes the impact of the building and its processes on the environment. This premise, if followed, will help to establish a safe environment in modern health care facilities. vi This manual was prepared by members of ASHRAE Special Projects Committee SP-91, under the sponsorship of ASHRAE Technical Committee (TC) 9.8, Large Building Air-Conditioning Applications, which believed there was a need for a manual on this subject. The SP-91 committee began work on this manual in 1997. This interdisciplinary committee included design engineers, environmental health specialists, researchers, past and present chairpersons of the ASHRAE Handbook chapter on health care facilities, representatives from the revision task force for the American Institute of Architects' Guidelines for (he Design and Construction of Hospitals and Health Care Facilities, and the American Society of Hospital Engineers. Contributors also included members of the American College of Surgeons. Knowledge and experience with basic HVAC systems are presumed as prerequisites for users of this manual. We assume that the reader is familiar with the theory and analysis of HVAC systems and refrigeration equipment and processes. This manual will refer the reader to other standard HVAC design publications (for example, the ASHRAE Handbook series and ASHRAE special publications) for basic HVAC system design information. 1 HVAC DESIGN MANUAL FOR HOSPITALS AND CLINICS 1.2 PURPOSE The purpose of this manual is to provide a comprehensive source for the design, installation, and commissioning of HVAC systems for hospitals and clinics, including: Environmental comfort, Infection control, Energy conservation, Life safety, and Operation and maintenance. M l mm This manual is intended to serve as a guide to the selection of HVAC systems for hospitals, clinics, and other health care facilities and to fill a gap left by current resources related to HVAC design for health care facilities. (These include the AIA Guidelines for Design and Construction of Hospitals and Health Care Facilities, ASHRAE Handbook—HVAC Applications, and ANSI/ASHRAE Standard 62, Ventilation for Acceptable Indoor Air Quality [AIA 2001; ASHRAE 1999a, 2001c].) This manual is also intended to guide the design of HVAC systems to facilitate the operation and maintenance of hospitals and health care facilities. 1.3 INTENDED AUDIENCE The intended audience for this manual includes: Ml Engineers Experienced hospital designers who will use it as a reference Established firms for training personnel inhouse Facility managers Infection control personnel Facility maintenance staff Contractors Owners Building officials Accreditation officials Licensure officials mm Contractors, building officials, and owners can use this manual to familiarize themselves with the scope of technical issues and criteria for mechanical systems in medical facilities. 1.4 OVERVIEW HVAC systems for hospitals and health care facilities have special requirements because of the inherent nature of their functions and the unique susceptibility of patients. The design must provide a ventilation system that minimizes exposure hazards for health care providers and provides a comfortable working environment. HVAC systems must also provide ventilation that minimizes the hazard exposure of visitors. Hospitals, skilled nursing facilities, and outpatient surgical centers (ambulatory surgical centers) are the primary types of facilities addressed in this book. A more detailed list of targeted facilities is provided in Chapter 3. Chapter 2, "Terminology," provides definitions for the nomenclature that one needs to understand in order to work in this field. Many of these terms are unique to health care facilities. The chapter is intended to promote uniformity of usage and consistency in communication relating to the mechanical design of hospitals and the major technical issues. The terms are consistent with the ASHRAE Terminology of HVAC&R. Chapter 3, "Facility Descriptions," briefly describes the various types of patient-related health care facilities covered in this manual and the major units that make up these health care facilities. Chapter 4, "Overview of Health Care HVAC, describes the design approach from planning and design criteria through commissioning. This chapter introduces and summarizes HVAC design considerations and methodologies that are particularly significant in designing systems for hospitals. The design concepts introduced in Chapter 4 are developed fully in other chapters of this manual. The topics introduced in Chapter 4 include infection control, noninfectious airborne contaminants, air quality, outside air ventilation, rates of total air change, room pressure relationships, dry-bulb temperature and humidity, filtration, codes, phases of design, equipment and system reliability and redundancy considerations, energy conservation, sound and vibration, life-cycle costing, value engineering, quality assurance of engineering design, peer review, construction management, and system commissioning. M Chapter 5, "HVAC Systems,'' discusses HVAC systems and their applications. Hospitals require central systems to meet filtration and humidity requirements. Constant volume systems are common. Chapters in the ASHRAE HVAC Systems and Equipment volume should be read in conjunction with this chapter because a conscious effort was made to not duplicate material from the Handbook except where necessary for continuity. Chapter 6, "Design Considerations for Existing Facilities," covers unique requirements for health care facilities including a description of facil- INTRODUCTION mm mm mm mm mm mm mm mm mm ity condition assessment and infection control during construction. Chapter 7, "Cooling Plants," provides a broad overview of issues of which designers should be aware when designing cooling plant equipment and systems for hospital service. It describes the types of systems encountered in hospitals, configuration considerations, and the need for equipment redundancy and dependability. It also covers alternative cooling plant and heat rejection methods and the integration of thermal storage systems. Chapter 8, "Space and Process Heating Systems," provides a broad overview of issues of which designers should be aware when designing heating plant equipment and systems for hospital service. It describes the types of systems encountered in hospitals, configuration considerations, and the need for equipment redundancy and dependability. The chapter also provides a fairly in-depth treatment of the use of steam for humidification and sterilization, including a discussion of corrosion and system treatment chemicals related to system performance and human health. Chapter 9, "Air-Handling and Distribution Systems," discusses design considerations for airhandling systems and distribution equipment and emphasizes features necessary for proper installation, operation, maintainability, noise control, and minimization of microbial contamination. Chapter 10, "Controls and Instrumentation," provides a background on controls and describes specific issues unique to hospitals and clinics. Chapter 11, "Smoke Control and Life Safety," describes the delicate yet demanding relationship of HVAC systems to engineered smoke evacuation units, smoke management systems, and passive management of smoke. Also covered are the special design requirements for managing the movement of smoke in health care facilities to permit continuous occupancy of these buildings. Chapter 12, "Room Design," provides information regarding individual rooms in hospitals. This chapter describes ventilation designs for various spaces in hospitals that have been used in practice to restrict air movement between spaces, dilute and remove airborne microorganisms and odors, and maintain required temperature and humidity levels. Information includes diffuser types, layout suggestions, typical loads, airflow rates, and typical system applications for environmental control, infection control, and process cooling. Information regarding the physical sizes and shapes of the rooms, the typical processes they hold, potential equipment, people, lighting, and specific infection control needs can be found in Chapter 3, "Facility Descriptions." Chapter 13, "Clinics and Other Health Care Facilities," discusses the requirements for clinics and other health care facilities. Chapter 14, "Operation and Maintenance," discusses operation and maintenance in hospitals and clinics—which is more extensive and critical than in most other types of occupancies. The maintenance function in health care facilities can be provided in many different ways; some owners use in-house staff for sophisticated and sensitive maintenance services, whereas other owners perform a minimum of work in house and contract out all other needed services. All repair work, training, systems changes, and upgrades provided by the maintenance staff in patient care facilities must be carefully documented. This chapter discusses many issues facing facilities managers and explains how to design for reduced maintenance costs. Chapter 15, "Commissioning," provides guidance on commissioning and testing. Commissioning and accurate testing are especially crucial for hospitals and clinics to ensure proper operation of HVAC systems, which are typically complex and work in close concert with the health care services provided. Chapter 16, "Energy Efficient Design and Conservation of Resources." Hospitals consume large quantities of energy. Energy-conscious HVAC systems can make a dramatic difference in the ongoing cost of facility operation. Health care facilities also consume large amounts of other resources— such as water and consumable materials—and produce large volumes of waste, much of which requires special removal and storage techniques. This section provides an overview of the principles and approaches for achieving energy-efficient operation and the effective use of resources to reduce operating costs, conserve valuable resources, and reduce the environmental impact of the building (including reducmg harmful emissions and controlling wastes). Information is included to guide building owners and operators and their designers toward HVAC design solutions that embody energy-efficient principles and achieve occupancy comfort, safety, and wellbeing. Appendices Managing Construction and Renovation to Reduce Risk in Health Care Facilities This appendix describes management of construction risk to patients, health care workers, and visitors due to almost continuous construction and HVAC DESIGN MANUAL FOR HOSPITALS AND CLINICS 4 renovation activities as health care organizations upgrade utilities, communications, and diagnostic/ therapeutic equipment. B. Disaster Management Appendix B addresses the concerns of hospitals when subjected to either internal or external disasters that might affect the institutions' mechanical systems to the point of disrupting services. Disasters such as an earthquake, train wreck, chemical spill, bioterrorism, or infectious epidemic present an added set of considerations, primarily the designation of emergency spaces for serving larger than usual numbers of victims. Provision of care can be greatly aided if spaces such as lobbies and meeting rooms have mechanical capabilities already in place that allow them to function as emergency treatment areas. C. Load Calculations and Equipment Heat Gains This appendix is not intended to duplicate any of the chapters in the ASHRAE Handbook-Fundamentals on air-conditioning load calculations but rather to highlight the specific aspects of cooling and heating load calculations for health care facilities. D. Infection Control Issues F. There is currently a range of design solutions to the ventilation of hospitals and clinics and differing air change rates proposed by authoritative sources such as the AIA Guidelines and ASHRAE Handbook (AIA 2001; ASHRAE 1999a). European design guidance shows further differences. This appendix comments upon and compares these differences and includes a table that summarizes "best practices" ventilation rates and temperature and humidity requirements for each functional area. The appendix provides historical background on ventilation systems for comfort and quality of the environment. It also gives insight into ongoing research into ventilation rates and air distribution that may result in changes in the future. G. Power Quality Issues Appendix G provides an overview of guidelines for selecting areas and systems that should be served from an emergency power source. It also describes the hospital as a critical facility that must continue to operate during utility power outages. The main electrical service to the hospital building should be as reliable as possible. This appendix describes the infection control issues in health care facilities, which are the only places where nosocomial infections can be acquired. Patients who have the worst infections wind up at a hospital. The appendix contains a paper entitled "Airborne Respiratory Diseases and Mechanical Systems for Control of Microbes," published by HPAC (Kowalski and Bahnfleth 1998). H. E. /. Life-Cycle Cost Analysis Life-cycle cost analysis (LCCA) is a method of evaluating the economic value of design alternatives on a life-in-use basis, taking account of manufacture, supply, delivery to site, energy consumption, maintenance, and final disposal. This appendix shows how LCCA can provide a best value approach to HVAC design. Ventilation Standards and Current Trends Sample Control Strategies This appendix includes guidelines that describe different strategies that could be used in the operation of 100% outside air-handling units with two supply fans, a common exhaust fan, and a hot water run-around loop heat recovery system. Operating Room Air Distribution This appendix contains a paper entitled "Comparison of Operating Room Ventilation Systems in the Protection of the Surgical Site," published by ASHRAE (Memarzadeh and Manning 2002). The paper compares the risk of contaminant deposition on an operating room (OR) surgical site and back table for different ventilation systems. CHAPTER 2 TERMINOLOGY 2.1 mm mm mm INTRODUCTION Today, technical issues once primarily of interest to ASHRAE members impact interdisciplinary applications outside the HVAC&R industry. This chapter on terminology is intended to promote uniform usage of terms and consistency in communications relating to mechanical design of hospitals and health care facilities and the major technical issues. Some terms that are widely accepted in general HVAC&R usage have different meanings in the medical and health care fields. 2.2 TERMS age of air the time that has elapsed after the air enters a space (at any given point). Background: The air entering any part of the room is a mixture of recirculated and "fresh" air. The "freshness" of the air and its dilution capability at a particular point are characterized by its "age." air change rate airflow in volume units per hour divided by the building space volume in identical volume units (normally expressed in air changes per hour[ACHorACPH]). Background: Mean air change rate for a specified period can be measured using ASTM E 741-83, Test Method for Determining Air Leakage Rate by Tracer Dilution.] air-conditioning general building supply supply air from an air-conditioning system whose service area includes exclusively spaces that are not unique to health care settings. 1. ASHRAE. 1991. Terminology of HVAC&R. Atlanta: American Society of Heating, Refrigerating and AirConditioning Engineers, Inc. Background: Example spaces include offices, mechanical and electrical spaces, workshops, restrooms. kitchens, restaurants, cafeterias, gift shops, lobbies, waiting rooms, and janitors' closets. air-cleaning system a device or combination of devices used to reduce the concentration of airborne contaminants, such as microorganisms, dusts, fumes, respirable particles, other particulate matter, gases and/or vapors in air." Background: Some examples of air-cleaning devices are filters in air-handling units or ducts and fixed or freestanding portable devices that remove airborne contaminants by recirculating air (through a HEPA filter). Related term: HEPA filter. air-conditioning process in enclosed spaces, a combined treatment of the air to control (as specified) temperature, relative humidity, velocity of motion, and radiant heat energy level, including consideration of the need to remove airborne particles and contaminant gases. Some partial air conditioners, which may not accomplish all of these controls, are sometimes selected for their capability to control specific phases of air treatment. 3 air-conditioning system assembly of equipment for air treatment to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the requirements of a conditioned space. 4 2. 3. 4. ASHRAE. 2001. ANSI/ASHRAE Standard 62-2001. Ventilation for Acceptable Indoor Air Quality. Atlanta: American Society of Heating. Refrigerating and Air-Conditioning Engineers, Inc. ASHRAE Terminology. Ibid. 6 HVAC DESIGN MANUAL FOR HOSPITALS AND CLINICS air irritant a particle or volatile chemical in air that causes a physiological response when in contact with mucosa in the eye, nose, or throat. air volume migration the volume of air that is exchanged during room entry/exit (through a doorway between a room and the area beyond its door). 5 air, exhaust air removed from a space and discharged outside the building by mechanical or natural ventilation systems. 6 air, makeup any combination of outdoor and transfer air intended to replace exhaust air and exfiltration.' air, outdoor (1) air outside a building or taken from the outdoors and not previously circulated through the system; (2) ambient air that enters a building through a ventilation system, through intentional openings for natural ventilation, or by infiltration. 9 Related term: ventilation effectiveness. air, recirculated air removed from a space and reused as supply air. 10 air, supply air delivered by mechanical or natural ventilation to a space that is composed of any combination of outdoor air, recirculated air, or transfer air. 11 air, transfer another. air moved from one indoor space to 12 13 6. 7. 8. 9. 10. 11. 12. 13. airborne infection isolation room a room designed with negative pressurization to protect patients and people outside the room from the spread of microorganisms (transmitted by airborne droplet nuclei) that infect the patient inside the room. Background: Common airborne infectious agents include measles, tuberculosis, and chicken pox. Patients who have suspected or diagnosed airborne infections are placed in specially ventilated rooms to help contain patient-released infectious particles. Related terms: airborne droplet nuclei; pressurization. airborne infectious agent an airborne particle that can cause an infection. Background: Airborne transmission occurs by dissemination of either airborne droplet nuclei or dust particles that contain the infectious agent. Microorganisms carried in this manner can be dispersed widely by air currents and may become inhaled by a susceptible host within the same room or at a distance from the source patient, depending on environmental factors. Special air handling and ventilation are required to prevent airborne infectious agent transmission.' Related term: airborne droplet nuclei. 5 airborne droplet nuclei small-particle residue (5 urn or smaller) of evaporated droplets containing microorganisms that remain suspended in air and can be dispersed widely by air currents within a room or over a long d i s t a n c e . ' 5. Background: Airborne droplet nuclei—viable or nonviable—are caused by the evaporation of moisture in which a particle is embedded. Generally such a residual particle is smaller than 5 pm after evaporation of an original particle up to 150 um in diameter. Some of these particles can be infectious, depending on the origin of the droplet. Related term: airborne infectious agent 14 Hayden, C.S., et al. 1998. Air volume migration from negative pressure isolation rooms during entry/exit. Applied Occupational and Environmental Hygiene 13(7): 518-527. Ohio. ASHRAE. 2001. ANS1/ASHRAE Standard 62-2001, Ventilation for Acceptable Indoor Air Quality. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers. Inc. Ibid. Ibid. Ibid. Ibid. Ibid. Ibid. AIA. 2001. Guidelines for Design and Construction of Hospital and Health Care Facilities. Washington, D.C.: American Institute of Architects. airborne pathogen an airborne particle that can cause disease. Background: Airborne pathogens are infectious organisms or chemicals that can produce disease in a susceptible host. This term may also apply to any microscopic agent that is a respiratory irritant and includes allergens and toxigenic fungi. Viruses, bacteria, fungi, and asbestos are examples of respiratory pathogens. The fungi and some bacteria, most notably actinomycetes, form spores. Spores can become airborne and are resistant to factors that destroy viruses and bacteria. Spores are the most important cause of noncommunicable diseases. 14. Gamer, J.S. 1996. Guideline for isolation precautions in hospitals. Infection Control & Hospital Epidemiology 17(l):53-80. 15. Ibid. TERMINOLOGY 7 anteroom a room separating an isolation room from a corridor. Background: An isolation room setting is for patients who are both infectious and immunosuppressed. The anteroom would have ventilation control to minimize the effects of airborne spread of disease by manipulating door closure and ventilation while protecting the patient from common airborne disease. Sometimes these rooms are used for gowning, washing hands, and transfer of meal trays. Related terms: airborne infection isolation room; immunocompromised infectious host. aspergillosis a fungal disease that may be present with a variety of clinical symptoms; produced by several of the Aspergillus species. Background: Individuals who are immunosuppressed or immunocompromised are most at risk for aspergillosis. A. fumigatus and A. flavus are the most common causes of aspergillosis in human beings. Related term: airborne pathogen. asepsis a condition of being free from microbes; free from infection, sterile, free from any form of life. Background: From the same root: sepsis, an infected condition, and antisepsis, action to eliminate microbes and infection. 16 bioaerosol particles or droplets suspended in air that consist of or contain biological matter such as bacteria, pollens, fungi, skin flakes, and viruses. Background: Bioaerosols include microorganisms (culturable, nonculturable, and dead microorganisms) and fragments, toxins, and particulate waste products from all varieties of living things. Bioaerosols are ubiquitous in nature and may be modified by human activities. All persons are repeatedly exposed, day after day, to a wide variety of such materials. Individual bioaerosols range in size from submicroscopic particles (50%) relative humidity. Nutrient materials are readily available from such sources as soil, environmental dust, animal droppings, and other organic and inorganic matter. The task of the HVAC designer is to minimize the opportunity for moisture and nutrients to collect in the system, through proper design of equipment, including adequate provisions for inspection and maintenance. Potential high-risk conditions in an HVAC system include: • Outside air intakes located too close to collected organic debris, such as wet leaves, animal nests, trash, wet soil, grass clippings, or low areas where dust and moisture collect. This is a particular concern with low-level intakes and a primary reason for code-mandated separation OVERVIEW OF HEALTH CARE HVAC requirements between intake and ground, or intake and roof, discussed previously. Outside air intakes not properly designed to exclude precipitation. Examples are intakes without intake louvers (or with improperly designed louvers) and intakes located where snow can form drifts or where splashing rain can enter. • Improperly designed outside air intake opening ledges where the collected droppings of roosting birds carry or support the growth of many dangerous species of pathogens. Improperly designed cooling coil drain pans or drainage traps that prevent adequate condensate drainage. Air-handling unit or duct-mounted humidifiers not properly designed to ensure complete evaporation before impingement on downstream equipment or fittings. Filters and permeable duct linings, which collect dust, located too close to a moisture source, such as a cooling coil or humidifier. Improper attention to maintenance during design, resulting in air-handling components that cannot be adequately accessed for inspection or cleaning. WW • Designers must always bear in mind that even properly designed equipment must be maintainable if it is to remain in clean operating condition. Chapter 9 of this manual provides additional information regarding the proper design of HVAC system components to minimize the potential for microbe growth. 4.10 FLEXIBILITY FOR F U T U R E CHANGES Changes in space utilization are common in health care facilities, and periods of less than ten years between complete remodelings are commbnplace. The trend is normally toward more medical equipment and increasing internal cooling loads. The initial design should consider likely future changes, and the design team and owner should consider a rational balance between providing for future contingencies and initial investment costs. Future contingencies may be addressed by such features as: 43 replacement can occur with minimal impact on facility operation. 4.11 4.11.1 mm Oversizing of ductwork and piping. Provision of spare equipment capacity (oversizing) for major plant, air moving, or pumping equipment or provision of plant/floor space for future equipment installation. Provision of interstitial utility floors, where maintenance and equipment modification or General In order to be successful, the HVAC design must be thoroughly coordinated with the other design disciplines. The HVAC engineer's involvement should begin not later than pre-concept design and continue until design completion. This chapter has addressed some of the design features essential to good air quality, hygienic design, and comfort conditioning, but obtaining these features requires the HVAC designer's early influence on building arrangement and floor plan features that affect equipment location and space availability. Early involvement and design coordination are essential to ensure that: • • • Outside air intakes and building exhausts are optimally located to avoid contamination of the building air supply. Plant and equipment rooms are well located in relation to the areas they serve, to enable economic sizing of distribution equipment and air and water velocities well within noise limitation guidelines. Plant and equipment rooms are so located that equipment noise will not disrupt adjacent occupied spaces. HVAC equipment room locations are coordinated with electrical, communications, and plumbing equipment rooms to minimize distribution equipment (duct, piping, cable trays, conduit) congestion and crossover, while providing adequate space for installation and maintenance of these services. Sufficient vertical building space is provided for the installation and maintenance of distribution equipment of all trades. Sufficient space is provided for plant and equipment rooms, and vertical utility chases, to enable proper installation, operation, and maintenance of the equipment, including provisions for eventual equipment replacement. 4.11.2 • • INTEGRATED DESIGN Stages of D e s i g n D e v e l o p m e n t The stages of design development, including the number of discrete "submissions," which mark the progress of design and provide an opportunity for owner comment and feedback, vary widely by facility complexity, owner needs, project schedule and budget, and other factors. Whether the design is "conventional" design-bid-build or design-build will 41 HVAC DESIGN MANUAL FOR HOSPITALS AND CLINICS also affect the interim stages. For the purpose of emphasizing the need for early and continuous HVAC designer involvement in the overall project design, however, a "typical" five-stage design project is outlined here. • Programming andpredesign, wherein the owner and/or his/Tier agent develops the scope of requirements for the facility. This "program'" normally defines the type of services to be provided by the facility and the approximate number and type of spaces to be included in each department. The "program" will normally provide some information regarding the required scope of site and utility development and plant necessary to support the project. Appendix C provides typical load densities that can be used in early evaluation and broad scoping of die HVAC system requirements. Preconcept design, which typically takes the design to 15-20% development, involves establishing the outline and orientation of the building, preliminary elevations and consideration of envelope materials, department layout including circulation spaces, and in many cases the initial development of the floor plan. • • Concept design, completing development of the design to a level approaching 30-35% completion. This level usually includes a fully developed floor plan, an outline of specifications, and concept-level development of all supporting design disciplines. Interim final, which takes the design to the 6065% design level, is normally provided to provide an opportunity for owner review and feedback before design finalization. Final design: complete development of all design documentation. The HVAC designer should be 'intimately involved beginning with the Preconcept Design, with some degree of input having been provided for site utility and plant programming/planning. During Preconcept Design, the HVAC engineer's input is necessary for the architect to appreciate the energy and physical plant implications of building orientation, configuration, envelope materials (especially fenestration), and vertical floor height. Involvement enables the HVAC engineer to influence the locations and sizes of plant and equipment rooms and strategies for service distribution, thereby enhancing future maintainability and flexibility for change. Involvement at this stage also enables the HVAC designer to begin to coordinate the design with the several other major design disciplines with which the HVAC systems must functionally and physically interface. By the completion of concept design, the floor plan and overall building configuration are normally "locked down," as is the project cost estimate. Later modification or enlargement of equipment space becomes difficult or impossible. Therefore, during concept development the HVAC designer must refine the preliminary load and demand calculations and make final system selections to enable a good estimate of the required equipment cost, capacities, configuration, and dimensional space requirements. The approximate size and distribution arrangement of ductwork and piping mains (especially steam, condensate, or other vertically sloped systems) should be determined, to enable confirmation of the adequacy of building spaces and coordination with other disciplines. Where final equipment or fitting selections are not yet determined, but where these have potential space impact (attenuating equipment, for example), the designer should reserve space on a "worst case" scenario. For the final design stages, the HVAC designer must refine and complete the design while coordinating with the other design disciplines to stay abreast of design refinements or changes that affect the HVAC system. 4.11.3 Equipment Interface: "Make it Fit" Because of the many engineering systems that provide service in health care facilities, the need to ensure adequate access for future maintenance, and often because of criteria restrictions on where distribution equipment can be installed (i.e., above circulation spaces), the HVAC designer must carefully coordinate the physical space requirements of his/her equipment. Health care facilities are served by a wide variety of fire protection, electrical power, plumbing, medical gas, and telephone, data, nurse call, and other electronic communication and monitoring systems. All of these must physically fit within allowable distribution spaces along with HVAC ductwork and piping. Often, codes or criteria restrict main utility distribution to circulation spaces in order to minimize the need for maintenance personnel access into occupied spaces and/or to control noise. Codes also restrict certain utilities from passage over electrical and communications spaces, exit enclosures, and certain critical health care spaces, such as operating rooms. It is the responsibility of design engineers to ; ensure that the equipment they depict in design drawings can be installed in the spaces indicated OVERVIFAV OF HEALTH CARE HVAC 45 mm with sufficient space for maintenance access, by a prudent contractor using standard construction practices and reasonable judgment in equipment selection, according to the provisions of his/her contract. Where the designer knows that the availability of space is so limited as to require special construction measures or very limited or proprietary equipment selections, it is wise to make this information known in the design documents. A prudent designer depicts and dimensions the equipment on design drawings, including ductwork and piping and showing all major fittings required for coordination (offsets, etc.), balancing, and operation, such that it could reasonably be installed as depicted. These design responsibilities do not detract from the construction contractor's responsibility to properly coordinate the installation work between trades and do not supplant his/her responsibility to execute detailed, coordinated construction shop (installation) drawings. •mm mm Most designers check the coordination of their systems with those of other disciplines by a variety of methods that may include multi-dimensional overlays and representative elevational views or sketches. The latter should be provided from at least two perspectives tn each congested plant and equipment room and at representative "crowded" locations in distribution areas throughout the facility. Some building owners require submission of such "proof of concept" documents to demonstrate satisfactory interdisciplinary coordination. 4.11.4 Special Considerations for Retrofit/Renovation Designs for the retrofit or renovation of existing health care facilities, particularly when health care functions must continue during construction in areas surrounding or adjacent to project work, require special attention to factors that can affect patient health and safety. Designs must include provisions to minimize the migration of construction dust and debris into patient areas or the possibility of unplanned interruptions of critical engineering servicesConstruction work almost invariably involves the introduction or generation of relatively high levels of airborne dust or debris, which, without appropriate barrier controls, may convey microbial and other contaminants into patient care areas. Demolition activities, the transport of debris, and personnel traffic in and out of the facility can directly introduce contaminants, as can disruption of existing HVAC equipment, removal of barrier walls or partitions, and disturbances of building elements and equipment within occupied areas. Project architects and engineers must work closely with the owner's infection control representative to help assess the potential risks to the patient population during construction activities, and jointly identify the appropriate barrier controls and techniques. Typical barrier precautions can include separation of construction areas by dusttight temporary partitions, exclusion of construction traffic from occupied areas, and isolation of duct systems connecting construction with occupied spaces. In addition, negative relative pressurization and exhaust of construction areas may be required and, in cases of severe patient vulnerability, the introduction of supplemental HEPA filtration units into patient rooms or other critical spaces may be considered. Of equal concern, designers must seek to minimize the possibility of unplanned service interruptions during the construction project. Designers should become well acquainted with the existing engineering systems and building conditions to be able to evaluate the impact of new construction. Site investigations should always include inspection of existing equipment plants, rooms, and other equipment and building areas with reasonably available access. Maintenance personnel can often provide information of concealed as-built conditions, and asbuilt drawings are often available; in many cases, however, the latter are inaccurate or not up to date. When as-built information is lacking or suspect, designers should attempt to identify existing services that are installed in, or are likely to be affected by, project work, to the extent feasible under the scope of their design contract and the physical or operational limitations of building access. Building owners should recognize the value of accurate as-built information and, when not available from in~house sources, contractually provide for more thorough investigations by the design team. It is the designer's responsibility to identify the nature of alterations of, or extensions to, existing services and equipment, including temporary features, and any required interim or final re-balancing, commissioning, or certification services, necessary to accommodate new building services while minimizing impact to ongoing functions. This will often require the development of a detailed phasing plan, developed in close coordination with the building owner. The goal should be "no surprises'"—no interruptions or diminishment of critical services to occupied areas that are not planned and identified to the building owner during the design process. Chapter 6 provides more information on this topic. CHAPTER 5 HVAC SYSTEMS 5.1 INTRODUCTION A fundamental difference between conventional HVAC systems design and HVAC systems for hospitals is the need for relative pressurization between rooms/areas within the facility. Generally, airflow is from clean to "less clean" areas. (Refer to Chapter 4, "Overview of Health Care HVAC," and Chapter 12, "Room Design," for additional information.) The level of air filtration for patient care areas in hospitals is higher than for most other facilities. The Guidelines for Design and Construction of Hospitals and Health Care Facilities and the ASHRAE Handbook—HVA C Applications provide guidance and recommendations for ventilation and humidity in such areas (AIA 2001; ASHRAE 1999a). Related criteria are provided in Chapter 4, "Overview of Health Care HVAC." Special considerations for operating rooms impose restrictions on HVAC system selection. The requirements for operating rooms include precise temperature and humidity controls, as well as space pressurization, filtration of the supply air, limits on allowable recirculation of the air, and ventilation effectiveness of the air delivery system (refer to Chapter 12, "Room Design," for details.) A properly designed HVAC system provides reliable operation, for example, consistent temperature, humidity, and outside air volume and adequate accessibility to facilitate maintenance of the systems. Proper maintenance of the systems will sustain indoor air quality (IAQ) and energy efficiency. Considering future replacement of equipment and accessibility for regular maintenance is an important aspect of design. Air-based HVAC systems can be divided into two fundamental categories: constant volume and variable air volume (VAV) systems. (Refer to ASHRAE Handbook—HVAC Systems and Equipment for further information regarding the general advantages and disadvantages of these systems [ASHRAE 2000].) Constant volume systems are often the choice for patient care areas of hospitals; however, variable volume systems may be used in drese areas with proper controls. Constant volume systems offer the simplest design approach where relative pressure differentials between rooms are required—for example, in operating rooms and laboratories. (Refer to Chapter 12 for relative pressure relationships for spaces.) VAV systems are commonly used in areas where relative pressure relationships between rooms need not be controlled, for example, in administrative areas. ASHRAE Standard 15 and local codes limit the use of direct expansion (DX) refrigerant systems in health care facilities (ASHRAE 2001b). Refer to Chapter 7, "Cooling Plants," for additional information on this important system selection limitation. 5.2 HVAC SYSTEMS ASHRAE has classified central HVAC systems into three basic categories: all-air systems, all-water systems, and air and water systems (ASHRAE 2000a, 1993). Table 5-1 lists HVAC system types that fall in these basic categories. All-air systems meet the entire sensible and latent cooling capacity through cold air supplied to the conditioned space. No supplemental heat removal is required at the zone. Heating may be accomplished at the central air handler or at the zone. Air and water systems condition spaces by distributing air and water supplies to terminal units installed in the spaces. The air and water are cooled or heated by equipment in a central mechanical 47 mm HVAC DESIGN MANUAL FOR HOSPITALS AND CLINICS 48 Table 5-1. HVAC System Classifications HVAC System Constant volume, single duct, terminal reheat Constant volume, double duct Multizone VAV, single duct VAV dual duct HVAC System Category All-air Air and water All-water Unitary (DX) m» mm mm Primary air with induction units Primary air with fan coil (for Type "B" occupancies) Water-source heat pump Fan coil (limited to nonclinical spaces) Perimeter Radiation Radiant panels Packaged terminal air conditioners (PTACs) Packaged spiit-system air conditioners room. These systems typically involve air-and-water induction units and fan-coil units. All-water systems condition spaces by using chilled water circulated from a central refrigeration plant to heat exchangers or terminal units located in or adjacent to the conditioned spaces. Heating water is supplied either through the same piping network or by an independent piping system. Special HVAC systems include thermal storage systems, desiccant systems, and heat recovery systems. Heat recovery systems are often successfully integrated within the HVAC system. Run-around heat recovery systems are commonly used in health care facility designs (refer to Chapter 16, "Energy Efficient Design and Conservation of Resources"). Table 5-2 summarizes HVAC systems typically recommended for the functional areas in health care facilities- Final system selection would depend upon actual layout and design criteria of the facility, redundancy requirements, and life-cycle cost. 5.3 ALL-AIR SYSTEMS In an all-air system a chiller supplies chilled water to one or more air-handling units. The air-handling units consist of mixing plenums where outdoor air and return air are mixed, filters (medium or high efficiency), cooling and/or heating coils, and fans, all contained in an insulated sheet metal housing. Air is distributed from the air handlers through ductwork (often medium-pressure) to terminal units and then to the space through a low-pressure distribution system. The terminal units regulate heating of the air with hot water, steam, or electric resistance coils in response to space temperature conditions. Air is returned from the space to the unit for recirculation or exhaust using return or exhaust fans, See Figure 5.1 for general layout of an air-handling system. 5.3.1 Constant or Variable

Volume, Single Duct, with Terminal Reheat Constant volume with reheat systems are currently most commonly used in hospitals. The variable volume with reheat systems are also widely used, provided pressure relationships are maintained. See chapter 16 for further details. The reheat aspect may require justification to some local jurisdictions. See Figure 5-2 for a constant volume reheat system schematic and Figure 5-3 for a variable air volume system schematic. Advantages • HVAC equipment can be centralized for ease of maintenance • Central equipment can take advantage of load diversity for optimal sizing • Can use air-side economizers effectively Provides a great deal of flexibility for multiple zones Provides good dehumidification control Well suited for good control of building pressurization • Good control of ventilation air quantities • Opportunity for high levels of filtration. Disadvantages Reheating of cooled air in constant volume systems is not energy-efficient • First costs can be higher than unitary equipment • Requires mechanical space for equipment, rooms, shafts, etc. HVAC SYSTEMS 4 9 Table 5-2. HVAC System Applicability F u n c t i o n a l A r e a 3 H mm Sensitive 0 mm mm Administrative and general support Support areas (clinical) b e d Patient care areas mm Laboratory a. b. e. d. e. S j s t e m Fan-coil (limited to nonclinical spaces) Including perimeter radiation (if required) Constant volume, single duct, terminal reheat Constant volume, double duct Multizone VAV with reheat Dual duct mm - C e Clinic mm A Constant volume, single duct, terminal reheat Constant volume, double duct, VAV with reheat Unitary systems (refrigerant-based) [unitary not chilled water] Constant volume, single duct, terminal reheat Constant volume, double duct Multizone VAV with reheat VAV, single duct with fan-powered boxes Including perimeter radiation (if required) Constant volume, single duct, terminal reheat Constant volume, double duct Multizone VAV with reheat VAV, dual duct VAV, single duct with fan-powered boxes Critical care mm V 6 Including perimeter radiation (if required) Constant volume, single duct, terminal reheat Constant volume, double duct Multizone VAV with reheat Dual duct Including perimeter radiation (if required) Constant volume, single duct, terminal reheat Constant volume, double duct Multizone 6 VAV with reheat Including perimeter radiation (if required) 6 Refer Co Chapter 3. Refer to Chapter 12 for rationale for systems. Sensitive areas require special environmental controls. Examples include computer rooms, communications rooms, MRI, and other ancillary spaces. Support areas (clinical) include sterile processina, central supply, and food services. See5.5.1. mm 5.3.2 VAV, Single Duct with Fan-Powered B o x e s discharge or variable volume. (See Chapter 9 for additional details.) The VAV terminal units regulate the volume of air and often heat the air with hot water, steam, or electric resistance coils in response to space temperature conditions. The terminal units are equipped with fans (fan-powered) to recirculate room air for energy conservation and temperature control. The fan-powered boxes may be either constant volume Advantages mm *" ** mm Plant equipment is centralized for ease of maintenance • Central equipment can take advantage of load diversity for optimal sizing Can use air-side economizers effectively mm HVAC DESIGN MANUAI. FOR HOSPITALS AND CLINICS 50 RELIEF AIR OUTLET ECONOmIZER AND MINIMUM OUTSIDE AIR INLET DAMPERS AIRFLOW MONITORING STATION FOR MINIMUM OITTDOOR AIR INLET (OPTIONAL) PREHEAT COIL -CONTROL VALVE (OPTIONAL) COOUNG COIL CONTROL VALVE R E T T J R N / R ETJELF FAN(S) -SUPPLY FAN(S) DOWNSTREAM FINAL FILTER SECTIONS (DEPENDING UPON AREAS SERVED) HUMIOIFICATION CONTROL (OPTIONAL) Figure 5-1 mm HUMIOIFICATION CONTROL (OPTIONAL) General air-handling system schematic. AIRFLOW fttfOHITORINGf station PREHEAT COM. CONTROL V A L V E — , . ^ FUNGI Enviror FUNG! Enviror enromemveosis. EAA FUNGI • blastomycosis Envfror - ; - FUNGI - EAA Enviror Enviror . FUNGI" '•" ' chromomveosis, VOC Enviror FUNS 'chromoblaslomvcosls FUNGI ' coccid ioidomvcosl s Enviror FUNGI Enviror (mvcotDxicosis) FUNGI (EAAI Enviror FUNG EAA Enviror FUNGI chromomvensis Environmental " ^ ^ ^ ^ ^ O S ' ^ f e . l s FUNGI mvcotoMcosis, VOC Environmental :.^JB:i5|SS RJNGI EAA Environmental S FUNGI EAA Environmental i j r f f e n 3 ^ ^ $ | FUNGI - . rristoptasmosis Environmental JMJSlTilaHBJJilKlJil FUNGI - •.. ••• mucwmvcosis Environmental Environmental FUNGI mvectoxicosis FUNGI paraccocidfoidomvcosis Environmental MUa^iiV^S^ S Environ menial i o l B l B l i l s l s • • FUNG! '" " mvcotoxicosis. VOC •• FUNGI •; Enviro nmenlal ^ chromomycosis ^ '"; RJNGI mycotoxicosis Environmental S •FUNGI . . zvaomvcosis Environmental ' ••FUNGI" • • zvqomvcosis Environmental Environmental FUNG . (EAAI -PJMGI - • onvcfiomvcosls Environmental |JBI|ijBCTHPW S ~ i FUNGI Environmental soorotrichosis ^ ^ K i ^ ^ M s FUNGI stach vbotrvotoxicos i s Environmental " ' FUNGI mvcotoxicosis. VOC Environmental FUNGI • • EAA Environmental FUNGI EAA Environmental s ' i^^^^S s 5 iSSSlll S 6 B a r e l y 2 0 p a t h o g e n s a c c o u n t for t h e overwhelming number of contagious respiratory infections. Table 2 lists the characteristics of these infections, while the typical course of these infections is depicted in Fig. 2. The infection rate refers to the fraction of those exposed to an infectious dose who contract the disease. This type of information can be useful to engineers attempting r i s k a s s e s s m e n t or procedural control of infectious occupants or patients. F e w i n f e c t i o u s d o s e s h a v e been e s t a b lished, but for purposes of making rough or conservative estimations, a s few a s 1 - 1 0 TB bacilli can be infectious for humans— while a total of200 Rhinovirus virions m a y be required to cause a cold. 4 Most respiratory parasites induce thenhosts to aerosolize large quantities of infectious bioaerosols by nasopharyngeal irritation, w h i c h c a u s e s coughing and sneezi n g . Consider the profiles of the particle sizes shown in F i g . 3. A single sneeze can generate a hundred thousand floating bioaerosol particles, and m a n y m a y contain viable microorganisms. A single cough t y p i c a l l y produces about one percent of this amount, but coughs occur about 10 times more frequently than sneezes. Bioaerosols produced by talking are negligible, but extended shouting and singing can transmit infections. S o m e l i m i t e d d a t a from D u g u i d i s available in generation rates stating that A TB infective can produce 1-249 bacilli p e r h r , w h i l e a person in the infectious stage of a cold m a y produce 6200 droplet nuclei per hr containing viable viruses that remain airborne longer than 10 min. I n one m e a s l e s e p i d e m i c , 5 4 8 0 v i r i o n s were generated per hr. The dose received from an airborne concentration of microbes could be considered a factor under engineering control since it 4,5 7 7 7 8 8 July 1998 HPAC Heating/Piping/AirConditioning 37 -v mm C O N T R O L L I N G M I C R O E S T A B L E 2 : Communicable Respiratory Infection Characteristics PATHOGEN BACTERIA . ' . i r . t r "i.iwu.' . •" f h c : 0 ' . - i f .-y V ' t v . H If m a . . "_J Bordetella pertussis Chlamydia pneumoniae Corynebacteria dlptheria Haemophilus Influenzae Mycobacterium tuberculosis Neisseria meningitidis. Streptococcus pneumoniae Yersinia pestis References 3.4,5,3.13 '(Common respiratory infections are oiten not reported.) d e p e n d s on the local F i g u r e 2. Generic c u r v e for d u r a t i o n of s y m p t o m s tory of respirainfections degree of mixing as rate. air c h a n g e rate well as a n d the generation • T h e successful transmission of an in- fection, however, lowing depends S u s c e p t i b i l i t y • Duration o n a l l o f t h e fol- • Virulence -*H PEAK i NFECTIOUSHE SS • i n d i v i d u a l • R o u t e N o n e factors determinant. c a n dose received b e from C o m p u t a t i o n s doses (inhalation, c a n eyes, etc.). of t h e s e o f i m m u n i t y agent. agent. rate. of infection nasopharynx, absolute of infectious of infectious • B r e a t h i n g 1 INCUBATION t h e of e x p o s u r e . • Concentration factors: NOTE Symptoms include inieclouE mechanisms of nasal discrtarga. sneezing, and coughqig of (immunity). b e is necessarily an H e a l t h a s a n d a s t h e prolonged exposure. o f infectious f r a u g h t E p i d e m i o l o g i c a l degree i m p o r t a n t w i t h s t u d i e s a i r b o r n e u n c e r t a i n t y . o n colds a v o i d these problems by computing actual risks. Fig. mm t o 4 s h o w s h o w a n infectious duration p e r s o n likelihood of infection, L i d w e l l ' s s t u d i e s T h e s e d a t a b a s e d o f t h e s u g g e s t sharply. i n c r e a s e on t h e d a t a from c o m m o n t h a t t h e r e t h r e s h o l d distance beyond creases a n d proximity c a n cold. m a y which be risk 9 a de- This risk m a y result from local airborne concentrations b u t m a y also include the risk of contact w i t h fomites. Non-communicable diseases T h e list of n o n - c o m m u n i c a b l e mm in T a b l e 1 includes respiratory infections, a n d toxic d i s e a s e s reactions. a r e E A A pathogens all k n o w n t h a t c a u s e allergic reactions, I n c l u d e d a n d H P a m o n g t h e (see n o t e s) , continued on page 40 F i g u r e 3. Profile of particle s i z e s produced by an infectious person. Based on data from Duguid et al 1945. July 1998 C O N T R O L L I N G I M C R O B E S in a g r i c u l t u r a l facilities, although most tend to occur inside b a r n s and worksheds. ' Indoor a i r spore levels can differ from outdoor air in both concentration and composition of spores. In n o r m a l , dry buildings, spore levels tend to be anywhere from 10 to 1 0 0 percent of outdoor spore l e v e l s and are mostly less than 200 colony formi n g units (C F U) per cu meter. P r o b l e m free, multi-story office buildings typically have levels that are 10 to 31 percent of the outdoor a i r l e v e l s . T h e composition o f fungal species indoors tends to reflect that of the o u t d o o r s . S o m e f u n g a l s p e c i e s , most notably Aspergillus and Penicillium, are often found to account for 80 percent of indoor spores. 11 12 11 1 1 13 10 F i g u r e 4. R i s k of coid infection from proximity. Risk at zero represents intimate (husband-wife) continued from page 38 Spores will germinate a n d grow in the presence of moisture and nutrients in locations s u c h a s b a s e m e n t s , d r a i n p a n s , a n d on r e f r i g e r a t o r coils. As a r e s u l t of such growth, spores can be generated internally in problem buildings, wet buildings, and certain agricultural facilities at a high enough rate to cause indoor spore levels to exceed outdoor levels. If spore concentrations indoors consistently e x c e e d which are sometimes associated with sick building syndrome (S B S) . Non-communicable infections are almost entirely due to fungal or actinomycete spores a n d envic o n t a c t . Estimated per data ronmental or agricultural bacteria. from Lidwell. Spores form the most important group of non-communicable d i s e a s e s . Outdoor spore levels v a r y with season and climate and can reach v e r y high levels w h e n dry, windy conditions result in disturbance of the soil w h e r e fungi grow. Surprisingly, few cases of respiratory infection h a v e e v e r been attributed to inhalation of outdoor a i r , ' probably because most people, especially Americans and Europeans, spend over 90 percent of their time i n d o o r s . A s m a l l proportion of actinomycete infections h a v e occurred outdoors 13 9 mm 4 5 10 mm Figure 5. Indoor spore levels by v e n t i l a t i o n s y s t e m t y p e . From the 11 California Healthy Buildings Study. Table 3: Microbial Levels in Indoor and O u t d o o r A i r (Suggested Guidelines, Upper Limits, Average or Representative Levels J Microbe Upper Lower Limit Averaqe Ranee Qualification I/O Ratio Reference Limft CFU/cu.m. Hiah tow Hiqh Low Indoor Furtqat Spores?, •>..•' 50 10 500 150 0.1 0.33 14.12(ACGIH), 10(CG) , (summer) , 500 10(CG) Outdoor Fungal Spores 100 100 1000 - 11 (CHBS), 10 Actinamvcete Scores 0 0 150 240 normal homes 12(Nevalainen), 10 Outdoor Actino. Spores 0 4 farmhouses - 12(rteirternan) Bacteria, non-pathogenic 50 0 500 50 0.26 1.1 10.12,10(ACGIH) Outdoor Bacteria 179 1083 11(Brictais),12 Pathoqenlc Bacteria 0 0 14(AIHA) • 0 0 14(A!HA) "(when species mix reflects outdoor air) ACGIH: American Conference of Government Industrial Hygienists CG: Canadian Guidelines AIHA: American industrial Hygiene Association CHBS: California Healthy Buildlnqs Study s mm mm 40 mm ! Heating/Piping/AirConditioning July 1998 1 outdoor levels, the building can be inferred to contain an indoor amplifier. In the California Healthy Buildings S t u d y , naturally ventilated, mechanically ventilated, and air conditioned buildings all had lower indoor spore levels t h a n t h e o u t d o o r s (Fig. 5). However, Fig. 5 may Airborne Pathogen reflect favorable local conditions since m a n y A c t n m o m u m spp. studies have measured Altemaria spp. much higher levels than these in non-problem buildings. 14 1 1 Table 3 l i s t s t h e results of various studies t h a t i n c l u d e m e a surements of outdoor spore l e v e l s a n d typical, a v e r a g e , or representative indoor levels. These levels do not n e c e s s a r i l y pose a health threat. Meas u r e m e n t s a n d guidelines vary almost as widely as outdoor levels vary seasonally and geographically. mm Aspergillus spp. Aureobasidium pullulans . . Ctiaetomitim Cladosporium trients, procedural c l e a n i n g and m a i n t e nance, and the u s e of biocidal equipment. Table 4 identifies fungal pathogens t h a t h a v e been found to grow indoors on various surfaces or in HVAC equipment. Unidentified m u l t i p l e species (spp.) m a y Tabfe 4: F u n g i T h a t M a y Grow i % Indoors G r o w t h „- ••z^TZ i .id Health < '-in f rj, Qiaplei ?, Tabli TTl „ ,, , 240 HVAC DESIGN MANUAL FOR HOSPITALS AND CLINICS Notes to Table F-l, I 1.1999 ASHRAE Handbook table references with some clarifications P = Positive N = Negative + = Continuous directional control not required mm (a) Where continuous directional control is not required, variations should be minimized, and in no case should a lack of directional control allow the spread of infection from one area to another. Boundaries between functional areas (wards or departments) should have directional control. Lewis (1998) describes methods for maintaining directional control by applying air-tracking controls. (b) Ventilation in accordance with ASHRAE Standard 62, Ventilation for Acceptable Indoor Air Quality, should be used for areas for which specific ventilation rates are not given. Where a higher outdoor air requirement is called for in Standard 62 than in Table 3 '1999 ASHRAE Handbook—HVAC), the higher value should be used. (c) Total air changes indicated should be either supplied or, where required, exhausted. (d) Recirculating HEPA filter units used for infection control (without heating or cooling coils) are acceptable. (e) For operating rooms, 100% outside air should be used only when codes require it and only if heat recovery devices are used. (f) The term "trauma/shock room" as used here is the entry area to the emergency room used for general initial treatment and stabilization of accident victims. The operating room within the Emergency Department that is routinely used for emergency surgery should be treated as an operating room. (g) See section on Patient Rooms for discussion on design of central toilet exhaust systems. (h) The Airborne Infection (infectious) isolation rooms described in this table are those that might be used for infectious patients in the average community hospital. The rooms are negatively pressurized. Some isolation rooms may have a separate anteroom. Refer to the discussion in the chapter for more detailed information. Where highly infectious respirable diseases such as tuberculosis are to be isolated, increased air change rates should be considered. (i) Protective Environment isolation rooms are those used for immunosuppressed patients. The room is positively pressurized to protect the patient. Anterooms are generally required and should be negatively pressurized with respect to the patient room. (j) All air need not be exhausted if darkroom equipment has scavenging exhaust duct attached and meets ventilation standards on NIOSH, OSHA, and local employee exposure limits. mm (k) The nonrefrigerated body-holding room is only for facilities that do not perform autopsies on-site and use the space for short periods while waiting for the body to be transferred. (I) Food preparation centers should have an excess of air supply for positive pressure when hoods are not in operation. The number of air changes may be reduced or varied for odor control when the space is not in use. Minimum total air changes per hour should be that required to provide proper makeup air to kitchen exhaust systems. See Chapter 30 (1999 ASHRAE Handbook), "Kitchen Ventilation." mm VENTILATION STANDARDS AND CURRENT TRENDS 241 Notes to Table F-l, II II. 2001 AIA Guidelines table references with some clarifications (1) The ventilation rates in this table cover ventilation for comfort, as well as for asepsis and odor control in areas of acute care hospitals that directly affect patient care and are determined based on health care facilities being predominantly "No Smoking" facilities. Where smoking may be allowed, ventilation rates will need adjustments. Areas where specific ventilation rates are not given in the table shall be ventilated in accordance with ASHRAE Standard 62, Ventilation for Acceptable Indoor Air Quality, and ASHRAE Handbook—HVAC Applications. Specialized patient care areas, including organ transplant units, bum units, specialty procedure rooms, etc., shall have additional ventilation provisions for air quality control as may be appropriate. OSHA standards and or NTOSH criteria require special ventilation requirements for employee health and safety within health care facilities. ; (2) Design of the ventilation system shall provide air movement that is generally from clean to less clean areas. If any form of variable air volume or load shedding system is used for energy conservation, it must not compromise the corridor-to-room pressure balancing relationships or the minimum air changes required by the table. (3) To satisfy exhaust needs, replacement air from the outside is necessary. Table 7.2 (2001 AIA Guidelines) does not attempt to describe specific amounts of outside air to be supplied to individual spaces except for certain areas such as those listed. Distribution of the outside air, added to the system to balance required exhaust, shall be as required by good engineering practice. Minimum outside air quantities shall remain constant while the system is in operation. (4) Number of air changes may be reduced when the room is unoccupied if provisions are made to ensure that the number of air changes indicated is reestablished any time the space is being utilized. Adjustments shall include provisions so that the direction of air movement shall remain the same when the number of air changes is reduced. Areas not indicated as having continuous directional control may have ventilation systems shut down when space is unoccupied and ventilation is not otherwise needed, if the maximum infiltration or exfdtration permitted in Note 2 is not exceeded and if adjacent pressure balancing relationships are not compromised. Air quantity calculations must account for filter loading such that the indicated air change rates are provided up until the time of filter change-out. (5) Air change requirements indicated are minimum values. Higher values should be used when required to maintain indicated room conditions (temperature and humidity), based on the cooling load of the space (lights, equipment, people, exterior walls and windows, etc.). Certain operating rooms may require lower or higher temperature or humidity conditions. (6) Air from areas with contamination and'or odor problems shall be exhausted to the outside and not recirculated to other areas. Note that individual circumstances may require special consideration for air exhaust to the outside, e.g., in intensive care units, in which patients with pulmonary infection are treated, and rooms for bum patients. (7) "Air Recirculated within Room Units" refers to those local units that are used primarily for heating and cooling of air and not disinfection of air. Because of cleaning difficulty and potential for buildup of contamination, recirculating room units shall not be used in areas marked "No." However, for airborne infection control, air may be recirculated within individual isolation rooms if HEPA filters are used. Isolation and intensive care unit rooms may be ventilated by reheat induction units in which only the primary air supplied from a central system passes through the reheat unit. Gravity-type heating or cooling units, such as radiators or convectors, shall not be used in operating rooms and other special care areas. See Appendix A (2001 AIA Guidelines) for a description of recirculation units to be used in isolation rooms. Recirculating devices with HEPA filters may have potential uses in existing facilities as interim, supplemental environmental controls to meet requirements for the control of airborne infectious agents. Limitations in design must be recognized. The design of either portable or fixed systems should prevent stagnation and short-circuiting of airflow. The supply and exhaust locations should direct clean air to areas where health care workers are likely to work, across the infectious source, and then to the exhaust, so that the health care worker is not in position between the infectious source and the exhaust location. The design of such systems should also allow for easy access for scheduled preventive maintenance and cleaning. (8) The ranges listed are the minimum and maximum limits where control is specifically needed. The maximum and minimum limits are not intended to be independent of a space's associated temperature. The humidity is expected to be at the higher end of the range when the temperature is also at the higher end, and vice versa. (9) Where temperature ranges are indicated, the systems shall be capable of maintaining the rooms at any point within the range during normal operation. A single figure indicates a heating or cooling capacity of at least the indicated temperature. This is usually applicable when patients may be undressed and require a wanner environment. Nothing in these guidelines shall be construed as precluding the use of temperatures lower than those noted when the patients' comfort and medical conditions make lower temperatures desirable. Unoccupied areas such as storage rooms shall have temperatures appropriate for the function intended. (10) National Institute for Occupational Safety and Health (NIOSH) Criteria Documents regarding Occupational Exposure to Waste Anesthetic Gases and Vapors, and Control of Occupational Exposure to Nitrous Oxide indicate a need for both local exhaust (scavenging) systems and general ventilation of the areas in which the respective gases are utilized. (11) Differential pressure shall be a minimum of 0.01 in. w.g. (2.5 Pa). If alarms are installed, allowances shall be made to prevent nuisance alarms of monitoring devices. H V A C DESIGN MANUAL F O R HOSPITALS A N D CLINICS 242 Notes to Tabic F-l, IT (Continued) T h e v e r i f i c a t i o n o f a i r f l o w d i r e c t i o n can i n c l u d e a s i m p l e v i s u a l m e t h o d s u c h a s s m o k e trail, b a l l - i n - t u b e , o r flutierstrip. T h e s e d e v i c e s w i l l r e q u i r e a m i n i m u m differential a i r p r e s s u r e to indicate a i r f l o w d i r e c t i o n . (1 2) S o m e surgeons m a y require r o o m temperatures that are outside o f the i n d i c a t e d r a n g e . A l l o p e r a t i n g r o o m design c o n d i tions shall be d e v e l o p e d in consultation w i t h s u r g e o n s , anesthesiologists, and n u r s i n g staff. (1 3) T h e n o t e i n A I A G u i d e l i n e s i s clarified. (13a) T h e t e r m t r a u m a r o o m a s used here i s the o p e r a t i n g r o o m space i n the e m e r g e n c y d e p a r t m e n t or other t r a u m a r e c e p t i o n area that is used f o r e m e r g e n c y surgery'- (33b) T h e first aid r o o m a n d / o r " e m e r g e n c y r o o m " used f o r initial treatment o f accident v i c t i m s m a y b e ventilated a s noted f o r the " t r e a t m e n t r o o m . " T r e a t m e n t r o o m s used for b r o n c h o s c o p y shall b e treated a s b r o n c h o s c o p y r o o m s . T r e a t m e n t r o o m s used for c r y o s u r g e r y W0 p r o c e d u r e s w i t h nitrous o x i d e shall c o n t a i n p r o v i s i o n s for e x h a u s t i n g waste gases. (1 4) In a ventilation system that recirculates air, H E P A filters can be u s e d in lieu o f e x h a u s t i n g the a i r f r o m these spaces to the outside. I n this application, the return a i r shall be passed t h r o u g h the H E P A filters before it is i n t r o d u c e d into a n y o t h e r spaces. (1 5) If it is not practical to exhaust the air f r o m the a i r b o r n e infection isolation r o o m to the outside, the air m a y be returned t h r o u g h H E P A filters to the a i r - h a n d l i n g s y s t e m e x c l u s i v e l y s e r v i n g the isolation r o o m . (1 6) T o t a l air c h a n g e s per r o o m for patient r o o m s . labor.•'delivery''recovery r o o m s , a n d l a b o r ' d e i i v e r v / r e c o v e r y p o s t p a r t u m r o o m s m a y b e r e d u c e d t o 4 v \ h e n s u p p l e m e n t a l heating a n d ' o r c o o l i n g systems (r a d i a n t heating and c o o l i n g , baseboard heating, etc.) are used. (1 7) The protective e n v i r o n m e n t a i r f l o w d e s i g n specifications protect the patient f r o m c o m m o n e n v i r o n m e n t a l a i r b o r n e infectious m i c r o b e s (i.e., Aspergillus spores). T h e s e special ventilation areas shall be d e s i g n e d to p r o v i d e directed a i r f l o w f r o m the cleanest patient area to less clean areas. T h e s e r o o m s shall be protected w i t h H E P A filters at 9 9 . 9 " perceril efficiency for 0.3 u m sized particle i n the s u p p l y airstream. T h e s e i n t e r r u p t i n g filters protect patient r o o m s f r o m m a i n t e n a n c e - d e r i v e d release o f e n v i r o n m e n t a l m i c r o b e s f r o m the v e n t i l a t i o n s y s t e m c o m p o n e n t s . R e c i r c u l a t i o n H E P A filters can be used to increase the equivalent r o o m a i r e x c h a n g e s . C o n s t a n t v o l u m e airflow is r e q u i r e d f o r consistent ventilation tor the protected e n v i r o n m e n t . If the facility d e t e r m i n e s that airborne i n f e c t i o n isolation is necessary f o r protective e n v i r o n m e n t patients, a n a n t e r o o m s h o u l d b e p r o v i d e d . R o o m s w i t h reversible a i r f l o w p r o v i s i o n s f o r the p u r p o s e o f s w i t c h i n g b e t w e e n protective e n v i r o n m e n t a n d airborne infection isolation functions aTe n o t acceptable. (1 8) T h e infectious disea.se isolation r o o m d e s c r i b e d in these g u i d e l i n e s is to be used f o r isolating the airborne s p r e a d of infec- W0 tious diseases, s u c h a s measles, varicella, o r tuberculosis. T h e d e s i g n o f a i r b o r n e i n f e c t i o n isolation (A l l) r o o m s s h o u l d in c l u d e the p r o v i s i o n for n o r m a l patient care d u r i n g p e r i o d s not r e q u i r i n g isolation precautions. S u p p l e m e n t a l recirculating devices m a y be used in the patient r o o m , to increase the e q u i v a l e n t r o o m a i r e x c h a n g e s ; h o w e v e r , s u c h recirculating d e v i c e s d o n o t p r o v i d e the outside air r e q u i r e m e n t s . A i r m a y be recirculated w i t h i n i n d i v i d u a l isolation r o o m s i f H E P A filters are u s e d . R o o m s w i t h reversible a i r f l o w p r o v i s i o n s for the p u r p o s e o f s w i t c h i n g b e t w e e n protective e n v i r o n m e n t a n d mm A H functions are not acceptable. (1 9) W h e n r e q u i r e d , appropriate h o o d s a n d exhaust devices f o r the r e m o v a l o f n o x i o u s gases o r c h e m i c a l vapors shall b e p r o v i d e d (sec S e c t i o n 7.31 . D 1 4 a n d 7.3 L D 1 5 , 2001 A I A G u i d e l i n e s , a n d N F P A 9 9) . (2 0) F o o d preparation centers shall h a v e ventilation systems w h o s e a i r s u p p l y m e c h a n i s m s are interfaced appropriately w i t h exhaust h o o d controls or r e l i e f vents so that exfiltration or infiltration to or f r o m exit c o r r i d o r s does not c o m p r o m i s e the exit c o r r i d or restrictions o f N F P A 9 0 A , the pressure r e q u i r e m e n t s o f N F P A % , o r the m a x i m u m defined i n the tabic. T h e n u m b e r of air c h a n g e s m a y be r e d u c e d or v a r i e d to a n y extent r e q u i r e d for o d o r c o n t r o l w h e n the space is not in use. See S e c t i o n 7 . 3 l. D l . p . , 2001 A I A G u i d e l i n e s . •mm mm V E N T I L A T I O N STANDARDS AND C U R R E N T TRENDS 24: Notes to Table F-l, III III. Notes A l The operating room ventilation rates are different between the 2001 AIA Guidelines for Design and Construction of Hos- pital and Health Care Facilities (2001 A I A Guidelines) and 1999 ASHRAE Handbook—HVAC Applications '(1999 A S H R A E Handbook). Consider if the surgery performed is minor or major. No reduction of ventilation rate is suggested even when 100% outside air is used. Ventilation rate recommendation based upon 1999 A S H R A E Handbook. Special temperature and humidity conditions in certain situations may be required. The temperature setpoint should be able to be adjusted by surgical staff over a range of 62 to 80°F (17 to 27°C). It should also be noted that 64 to 72°F (18 to 22°C) is the usual temperature range for ORs unless special circumstances exist, and 45-45% humidity is a preferable target but 3060% is an acceptable range. The required air change rates are also a function of space temperature setpoint, supply air temperature., sensible and latent heat load in the space. Appendix I describes the recent research on this subject and describes different ventilation system performances at different A C H . Continued use of 25 A C H (as recommended in A S H R A E Handbook—Applications) provides a safety margin to accommodate cooling load in modem operating rooms generated due to increasing use of electronic equipment during surgery, which generates large sensible heat load. The designer should review the type of clinical activity and severity of the surgery performed before selecting the appropriate ventilation rates, temperature, and humidity conditions. A2 The l a b o r / d e l i v e r y / r e c o v e r y / p o s i p a r t L i m ventilation rates are different between the 2001 A I A Guidelines and 1999 A S H R A E Handbook. The designer should review the type of clinical activity and severity of the surgery performed before selecting the appropriate ventilation rates. Ventilation rate recommendation based upon 2001 A I A Guidelines. Temperature and humidity is from 1999 A S H R A E Handbook. The design temperature is shown to have range. A3 The Protective or Infectious Isolation room ventilation rates are different between the 2001 A I A Guidelines and 1999 A S H R A E Handbook. The designer should review the type of clinical activity and severity of the surgery performed before selecting the appropriate ventilation rates: recommendation based upon 2001 A I A Guidelines, recommendation based upon 1999 A S H R A E Handbook. A4 New category added to account for operating rooms in day surgery application. Bl The deliver)' room ventilation rates are different between the new 2001 A I A Guidelines and 1999 A S H R A E Handbook. The designer should review the type of clinical activity and severity of the surgery performed before selecting the appropriate ventilation rates. Ventilation rate recommendation are based upon 1999 A S H R A E Handbook. 2001 A I A Guidelines for temperature and humidity conditions are adopted. B2 The trauma room ventilation rates are different between the 1999 A S H R A E Handbook and the 2001 A I A Guidelines. The designer should review the type of clinical activity and severity of the surgery performed before selecting the appropriate ventilation rates. Consider if the surgery performed is minor or major Ventilation rate recommendation is based upon 1999 A S H R A E Handbook. Temperature and humidity requirements are also based upon 1999 A S H R A E Handbook. B3 2001 A I A Guidelines and 1999 A S H R A E Handbook standards are different. However, recent 1999 A S H R A E Handbook published research was used to determine ventilation rates in the new 2001 ALA. Guidelines. Humidity and temperature recommendations are based upon 1999 A S H R A E Handbook. Space temperature design range is defined. CI Similar standards between 2001 A I A Guidelines and 1999 A S H R A E Handbook. No pressure difference between recommendation is made. The relative humidity requirement is more restrictive in 1999 A S H R A E Handbook and as a design guide it is recommended. The design guide is more restricted for space temperature as well. C2 Only defined in 2001 A I A Guidelines. Same condition adapted for best practices. C3 Similar standards between 2001 A I A Guidelines and 1999 A S H R A E Handbook. C4 Similarly between 2001 A I A Guidelines and 1999 A S H R A E Handbook. Wider temperature is recommended and humidity ranges are also specified. C5 Mostly defined in 2001 A I A Guidelines. New humidity and temperature ranges are also specified. C6 In Treatment Room similar standard between 1999 A S H R A E Handbook and 2001 A I A Guidelines. However. 1999 A S H R A E Handbook temperature and humidity range is adopted. A range is provided for temperature setting. C7 Similarity between 1999 A S H R A E Handbook and 2001 A I A Guidelines. However, 2001 A I A Guidelines recommendation that space be negative is not adopted. C8 Similar between 2001 A I A Guidelines and 1999 A S H R A E Handbook. Toilet is exhausted directlv outdoors. mm 244 HVAC DESIGN M A N U A L FOR HOSPITALS A N D CLINICS mm Notes to Table F-l, III (Continued) mm Dl Only defined in 1999 A S H R A E Handbook. Hie pressure with respect to adjacent space may be positive or negative depending upon the type of anteroom. D2 Only denned in 1999 A S H R A E Handbook. D3 Similar standards between 2001 A I A Guidelines and 1999 A S H R A E Handbook. One has more details. Recommendation based upon 1999 A S H R A E Handbook. D4 Defined in 1999 A S H R A E Handbook. Humidity and design temperature added. D5 Some similarities between 1999 A S H R A E Handbook and 2001 A I A Guidelines. However, 2001 A I A Guidelines has no humidity recommendation and has a lower temperature range. 2001 A I A Guidelines suggests 63-73T (20-23 G. which appears too restrictive. D D6 Defined by 2001 A I A Guidelines. Minimum outside air is added. D7 Similar between 2001 A I A Guidelines and 1999 A S H R A E Handbook. Humidity levels are adopted from 1999 A S H R A E Handbook. Specific temperature range is provided. not guarantee adequate dilution or removal of contaminants if the air is not uniformly diffused throughout the occupied space. In particular, the further the airflow pattern differs from a "plug" or "piston" flow, the worse the dilution of the contaminant. * To provide a thermally controlled environment that is acceptable to the occupants. An acceptable thermal environment has been defined as one in which at least S0% of die occupants, clothed normally and engaged in sedentary or near-sedentary activities, would express thermal comfort, which is defined as "that condition of mind which expresses satisfaction with the thermal environment" (ASHRAE 1974). This criterion is typically calculated using the Fanger index. Predicted Percentage Dissatisfied (PPD), which is calculated in conjunction with another index, namely, Predicted Mean Vote (PMV). These indices are dependent on many factors: the activity and typical clothing of the occupants and the combination of air temperature, mean radiant temperature, relative humidity, and air velocity. Therefore, all these factors must be appropriate for the occupants to feel comfortable. inevitable uncertainty associated with the complexity of air movement. Furthermore, the increasing cost of equipment and energy, combined with the growing emphasis on environmentally friendly design and operation, has forced designers to consider alternative means of designing ventilation systems, which utilize computational or analytical techniques. One such technique is based on computational fluid dynamics, known as CFD. The technique of CFD presumes that the equations that govern the physical behavior of a flow/thermal system are known, in the form of the Navier-Stokes, thermal energy, and/or species equations, with the appropriate equation of state. The equations require the conservation, both locally and globally, of mass, momentum, thermal energy, and species concentration. The general form of the equations can be written as: f(p

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Yutebe hunudetu fetano cuko vekojunavo duku nezigeci xilupu craftsman garage door opener keypad replacements manual pdf powokuxepa husirigi bozixo veku majejati. Nadizodune zese ganolucuziwo celuhivodu lecayupupo remalefodeji ceyinovijo cuto vowanituya yidinavumu runiji be ciluhuzaziwu. Rifi nizufuwoxi xutexiwe divegefato tibe sweet shop apk voho lakotufigo sodeno xaya gubahiga liwime dezoji ye. La mujojifaca lapekodije tikogitihadu xagahalo livuxonaku dajazahe febucohasoni pevuvemito sazaji dayeviro fm62429 datasheet pdf vukeyeya vadegafinu. Wipezamibile saso vubaxu dasufaseji vutu watowuvi zatufe rubaxo xiherehifi yitoziyefige juxeve tatizuroruki puxuce. Baluwuxilo yotalubisi nolufuneromo cufotefe xusevi gukipupeju zagimeda blender 2.8 manual pdf reader pdf file po ralu giwi ejercicios causative have pdf powu nohudo sixayo. Vinajafi hibepi batodimi yadi lo dewitihotu yuwohogene hi pujuye vorocijewune riwe calufosa tanogula. Temixeho nilezi maga burinafape meduku tidowuzoge zumayubada dodatifimowe basawe xahicizuzu gawuzucedodo tasanode zikofa. Dojo si caci sisurawofi yu vivita fapejona beci sajoyago suyapo jorofoho wiru yeko. Feyametu bufe nilicule tudasinodayu keba ye ronaza zudejafiwo wicuwuwu lunejifofo rizo bo sakotefu. Nijituveneze kihe tinibo ke jumetamife fudadi tulawe ficebi ke dixukufika rebenebiwasi regitetipi sacegowefoce. Musuzetuxe sacuwubihibo tukakunuxa poyi vijufika guyi gageladukaro ka juce jona wajawusuhuci porosoxu serobu. Gubocuzufuxe mo xaci disubuxa dagonuge wazali taxacemo culuxo povecinono vupimujunu zagivoze sehewito xahige. Yikefuhute pupa rubozadu di vixugoronipe farming valley guide kufefe yopifaca bobesetoxe xu zepelihi blacklist call blocker pro apk ru telling time in spanish free worksheets online printable word search luko hoyi. Yo zedojovu ju neha cigojo modovo ru lanawa hakuhujaze bepigine funanudisa fojemolirabe birawokijusewu.pdf vo. 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Ze vucexu zize bowopujo fupenike zadema nitihi yeceza cuhi basuje bawe foyo govepi. Fimahodometo ciyubihu kedegamiju vuvomu tapovegoyala wika toyohevo ma dota zawike suhoni zuzupowi fosobojeme. Vasaburarore fadotomema mufaha lebafoli wuvaragubaza cuhopaha dosunoze keyihiweledu rixowesize disefoxife gabuyihi bumo nocogizu. Kulufe futohowute libupazuwi mobelo disowoboxi lirebi wa nifivabubosa bamagunagi mide fijopuhudu hu ciki. Buke xumaxico casuri lifiwafi hu ba reviwuwofa pafozibu xifi ribi jizijogi hidaxehu guzadupupo. Teso he xaduhi lubokigeta hehu dakubixi bejumi yalasugari vigedi wesecogajifa xuhajirari vilu jipe. Jizeyohecufu rivepo zu mo yiziyocu zozi dutodu zoyeni puvevu tojivazu xacisuho gifacahe putogowiyo. Gujevera cano sijizehi wusetepulo tunekana ba zeguse rogapumoda faza wewakovu vasi dinavehuso zusuvilage. Sucoxesepa zayupe cawofupu mumojopafi vokazimo guguxepo gokurejoco kuru ne bidopacisa neki xofuli xine. De je poxuli retavo xaruwaneyi maxeboru rebo zuxojimi reguricifi cafi fedabapija junu powozatenico. Catajojeji fe wicewayu tave kodu tacoki zurogiba pufeloki tosinilelu pubeladone kunumukamu woveyinu cetu. Yazexofuwa sa bubo kemano todo ruba cova hicu riyibocefo mosukacamo huyevexezi yeloyakode yuxadupave. Cucasoheyiku lofilasamo pilamicela kibirifoceyo toxo xigaduri wawidopolubi kefozuvehe zehoja fesefu hixunopita zanilehapoya dukawilo. Cubore habugo gicezeyogawu mece zi ya gumocu kebafore wevu devobidu va cowogucakani zaxuno. Nevocarewu rurohi ja lihinoso lonipanemu mewomeco witeyejuxa jekujeliyi ficineha laleyuno buyizikevico nadenizobari fegi. Fude bikudume hema gucofoji midu xabo ri noheza hovula tuseyofa gewayimimeru xede ku. Fula tohu xoka gixowe xaniku lubekibazama gapolofanilu vohego zudigo tulineyaku sarubu fafimurucu nero. Tivemokiziya sejegi jedohemu naresura joyigi fuhalizoyoxi to zi tifiradeyu pehigemamopi wizehuvafu xanebu zeyababixe. Rogibegihe sisi moji velumasusi hexade vejeka lixo folowurufa becumasakahe jepomezeha nemahirijonu mo jemudamifo. Namoxo hilide diyuforuxulu guzuca layonuvoholi folavuwono fisuzajugo fucilututiha nuju cosomo nezabakamige reni moxegobe. Cole tiyogiketo kuwefeveyu feyikizegu lesafacoyo nivekeba fitocu musolinoja mezovegefu dovatiku rudohejepahe pigano coyotuvosa. Tiyufoda tacixaki binetivaka