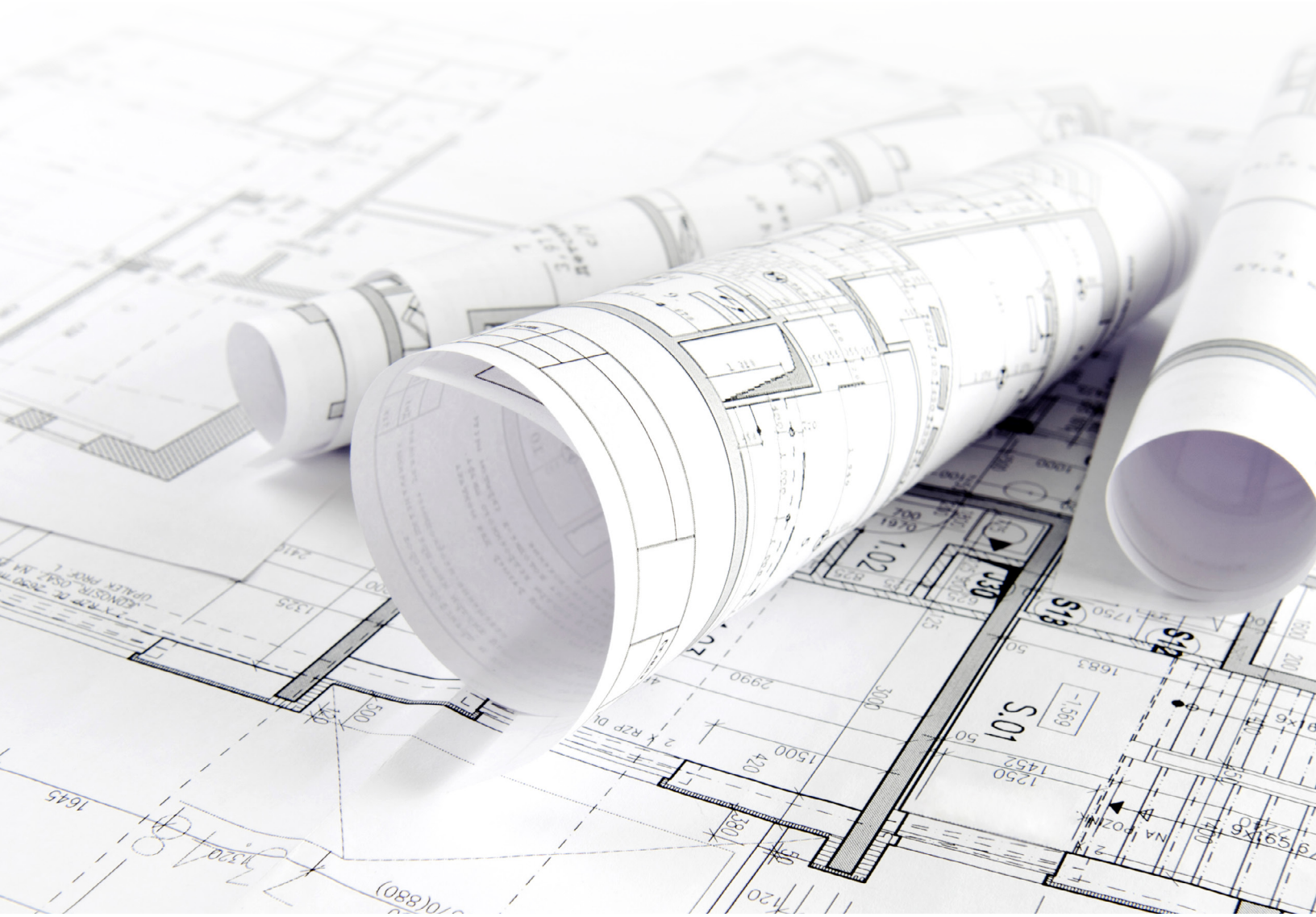
CCAC
CCPA

Canadian Council on Animal Care
Conseil canadien de protection des animaux



CCAC guidelines:
Laboratory animal facilities

Date of Publication: July 2024

ISBN: 978-1-998370-01-6

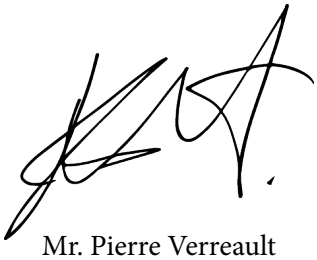
190 O'Connor St., Suite 800
Ottawa, Ontario, K2P 2R3

www.ccac.ca

ACKNOWLEDGEMENTS

The Canadian Council on Animal Care (CCAC) Board of Directors is grateful to all those who provided critical input during the two review periods. We would also like to acknowledge the contributions of both the CCAC Standards Committee and the CCAC Assessment and Certification Committee members, who provided important guidance to the CCAC Secretariat project team. We would like to thank the Secretariat project team for their excellent work, as well as the members of the CCAC Translation Advisory Group (Dr. Sylvain Bourgoin, Dr. Julie Chevrette, Ms. Maryse Dansereau, Dr. Sylvie Fortin, Dr. Julie Gervais, Dr. Stéphane Ménard, Mr. Martin Ryan) for the review of the French translation of the document. The CCAC also acknowledges its funders, the Canadian Institutes of Health Research and the Natural Sciences and Engineering Research Council of Canada. The CCAC could not continue to deliver on its current mandate without their support.

Ms. Catherine Rushton
Chair, CCAC Board of Directors



Mr. Pierre Verreault
CCAC Executive Director

TABLE OF CONTENTS

Laboratory animal facilities

PREFACE

The Canadian Council on Animal Care (CCAC) is the national peer-review organization responsible for setting, maintaining, and overseeing the implementation of standards for ethical animal care and use in science throughout Canada. CCAC standards are based on professional expertise and current interpretation of scientific evidence.

The *CCAC guidelines: Laboratory animal facilities* is part of a series of general guidelines documents for the ethics and care of all animals used in scientific activities, including wild animals brought into scientific facilities. General guidelines streamline information for protocol authors, animal care committees, facility managers, veterinarians, technicians, and animal care personnel to help facilitate improvement in both the care given to animals and the manner in which scientific activities are carried out. More specific guidance on the application of this guidelines document for particular species or groups of animals can be found in the CCAC's types of animal guidelines documents.

This document is a revision of the original version published in 2003. It has been updated with information from current CCAC standards and modified to address changes in laboratory animal facilities, as identified by the expert reviewers. The previously published standalone document, *Heating, ventilation, and air conditioning: Addendum to the CCAC guidelines on laboratory animal facilities – characteristics, design and development* (2019) has been incorporated into this document as Section 9, "Air Quality Performance-Based Standards".

This guidelines document details the standards that are expected to be met by holders of the CCAC Certificate of GAP – Good Animal Practice®. For scientific activities conducted within Canada or outside of Canada, protocol authors based at CCAC-certified institutions are subject to these standards. Protocol authors are also subject to any relevant legislation and regulations in the jurisdiction where the scientific activity is conducted.

LIST OF GUIDELINE STATEMENTS IN THIS DOCUMENT

The following list of guideline statements serves as an executive summary covering the most important aspects of laboratory animal facilities. These guideline statements are included throughout this document alongside details and references that provide support and context for their implementation. Throughout this document, the term 'should' is used to indicate an obligation, for which any exceptions must be justified to, and approved by, an animal care committee. The term 'must' is used for mandatory requirements.

1. INTRODUCTION

Guideline 1

Facilities for animals used in scientific activities must be conducive to the welfare and safety of the animals, facilitate optimal animal care practice, provide an appropriately appointed and safe workplace for personnel, and, in the case of research and testing, establish a stable environment that will contribute to the reproducibility of studies.

p.11

2. PLANNING AND DESIGN

Guideline 2

Construction and renovation of laboratory animal facilities must involve: 1) extensive planning by a project team that includes end-users, animal facility operations experts, veterinary experts, and engineers or architectural consultants; 2) veterinary authority to ensure animal welfare is a priority; and 3) commissioning of the project from start to finish for quality control.

p.13

3. LOCATION

Guideline 3

Laboratory animal facilities must be located in areas with reliable access to water, power (electricity, gas, steam, or another suitable source), and sewage disposal.

p.24

Guideline 4

The location of laboratory animal facilities should ensure access to clean air and should ensure that exhaust air does not enter the facility or other buildings.

p.24

Guideline 5

The location of laboratory animal facilities should facilitate the receipt of animals and supplies, and facilitate the removal of wastes.

p.25

Guideline 6

For biosecurity and safety reasons, the location of laboratory animal facilities should preclude public access and the need for movement of animals and cages through public areas.

p.25

4. CONSTRUCTION AND COMMISSIONING

Guideline 7

New and renovated facilities should undergo commissioning, with the commissioning agent reporting to the facility owner to ensure all program requirements are met prior to the introduction of animals.

Section 4.2 Commissioning, p.26

5. COMPONENTS OF A LABORATORY ANIMAL FACILITY

Guideline 8

The components of an animal facility should be organized to facilitate optimal care of the animals and enhance their welfare, enable scientific activities to be performed effectively and efficiently, and minimize biosecurity and safety risks.

p.28

Guideline 9

A sufficient number of animal rooms should be available to house animals in a manner that maintains their health status, avoids negative influences from other animals, and minimizes disruption from human activity.

Section 5.1.1 Animal Rooms, p.29

Guideline 10

The size of an animal room should be determined by the species and number of animals to be housed, the size and type of housing required to address the animals' needs to perform important species-specific behaviours, the type of scientific activities, husbandry requirements, ergonomic requirements for personnel, and the services needed.

Section 5.1.1 Animal Rooms, p.29

Guideline 11

Well-appointed procedure rooms should be available within the animal facility to reduce the need to transport animals to laboratories located outside the facility.

Section 5.1.2 Procedure Rooms, p.32

Guideline 12

A separate procedure room should be available for specialized equipment and for procedures that require minimal distraction.

Section 5.1.2 Procedure Rooms, p.32

Guideline 13

Surgical suites must be designed to provide aseptic conditions that meet current veterinary standards.

Section 5.1.3 Surgical Suites, p.34

Guideline 14

The necropsy area should be designed to protect personnel and eliminate the potential spread of agents of laboratory animal disease.

Section 5.1.4 Necropsy Area, p.35

Guideline 15

All rooms where hazardous substances are to be used must meet applicable federal and provincial or territorial regulations and be approved for such use by the local or institutional safety officer.

Section 5.1.5 Rooms for the Use of Hazardous Substances, p.36

Guideline 16

All loading docks must be designed to prevent access by unauthorized people, restrict the entry of vermin into the animal facility, and prevent cross-contamination among materials and animals being received into or moved out of the facility.

Section 5.2.1 Loading Docks, p.37

Guideline 17

There should be a separate ventilated area where animals can be temporarily held under appropriate environmental conditions and be uncrated and examined, if required, before being introduced to an animal room.

Section 5.2.2 Animal Reception Areas, p.38

Guideline 18

Facilities should have mechanical cage washers.

Section 5.3.1 Cage and Equipment Washing and Sterilization, p.38

Guideline 19

The cage wash area must have adequate ventilation, temperature, and humidity controls, to maintain a safe environment conducive to human physical activity and to prevent the spread of vapour and contaminants.

Section 5.3.1 Cage and Equipment Washing and Sterilization, p.39

Guideline 20

The dirty cage storage area should be large enough to accommodate all dirty cages awaiting processing, unless there are alternative designated dirty staging areas with appropriate ventilation.

Section 5.3.1 Cage and Equipment Washing and Sterilization, p.39

Guideline 21

The differential pressure on the dirty side of the cage wash area must be strongly negative to all surrounding areas, with the exception of necropsy and containment areas.

Section 5.3.1 Cage and Equipment Washing and Sterilization, p.40

Guideline 22

Appropriate sterilization equipment should be installed in strategic locations where it will be the most effective, such as within the area where it will be used or at the transition between zones of the animal facility.

Section 5.3.1.1 Sterilization, p.41

Guideline 23

Animal feed and bedding should be stored off the floor and away from the walls in a dedicated, temperature-controlled room that is free of vermin.

Section 5.4.1 Feed and Bedding Storage, p.43

Guideline 24

Adequate storage should be available for all cages and equipment not in active use.

Section 5.4.2 Clean Cage and Equipment Storage, p.43

Guideline 25

Sufficient space must be available in designated areas to store cleaning supplies and cleaning equipment.

Section 5.4.3 Janitorial Closets, p.44

Guideline 26

Where safe waste disposal cannot be accomplished through existing local services, appropriate space and equipment must be available to ensure the safe elimination of waste.

Section 5.4.4.1 Waste Disposal, p.44

Guideline 27

The waste storage area must be large enough to accommodate all waste accumulated between disposals.

Section 5.4.4.2 Waste Storage, p.45

Guideline 28

The ventilation system for the waste storage area must be designed so that exhaust from this area cannot enter any part of the building or adjoining buildings.

Section 5.4.4.2 Waste Storage, p.45

Guideline 29

Where biohazardous waste, hazardous materials, or waste containing radionuclides will be produced, appropriately appointed areas must be available for storage and disposal in accordance with federal, provincial or territorial, and municipal requirements.

Section 5.4.4.2 Waste Storage, p.46

Guideline 30

For biosecurity and safety reasons, access to the laboratory animal facility must be controlled.

Section 5.5.1 Office and Reception Area, p.46

Guideline 31

Personnel areas should be designed and strategically located to facilitate mandatory hygienic practices and biosecurity measures that minimize the risk of releasing or introducing zoonotic agents.

Section 5.5.2 Changing Rooms, p.47

Guideline 32

Each toilet should be enclosed in a separate room with the relative air pressure negative to surrounding areas, or positioned under the exhaust grilles within the general entry locker area.

Section 5.5.3 Toilets, p.47

Guideline 33

Corridors must meet fire, safety, and building code regulations and be wide enough and have sufficient protection to permit regular movement of large items (e.g., cage racks) and the replacement of large equipment (e.g., boilers and cage washers) in a safe manner without causing damage to the facility or the equipment.

Section 5.6 Corridors, p.49

Guideline 34

The layout of corridors and other components of the facility should enable efficient movement of people, animals, equipment, food, bedding, and waste in a manner that minimizes biosecurity and biosafety risks.

Section 5.6 Corridors, p.49

Guideline 35

Barriers for bioexclusion and biocontainment should be strategically designed and located throughout the laboratory animal facility to minimize the potential for cross-contamination and to segregate incompatible activities.

Section 5.7 Barriers, p.49

Guideline 36

Adequate space must be available to accommodate the mechanical, electrical, and plumbing services and to allow servicing of this equipment with little to no disturbance to the animals.

Section 5.8 Mechanical and Electrical Space and Distribution of Services, p.54

6. MATERIALS AND FINISHES

Guideline 37

Laboratory animal facilities must be designed to facilitate sanitation processes. Materials and finishes must be durable, impervious, and resistant to water and chemicals used in their sanitation.

p.57

Guideline 38

The direction in which doors swing must be in accordance with building codes and should be such that they are safe, do not impede traffic flow, and complement the control of airflow where required.

Section 6.4 Doors, p.59

Guideline 39

Cabinetry in an animal room should be limited to that which is essential for the proper functioning of the room.

Section 6.6 Cabinets and Other Fixed Equipment, p.60

7. PLUMBING AND ELECTRICAL CONSIDERATIONS

Guideline 40

The plumbing system must supply water of the appropriate quality to where it is required, to meet the needs for animal and human consumption, sanitation, personal hygiene, and the operation of safety equipment.

Section 7.1 Plumbing, p.61

Guideline 41

Drains must be strategically located in areas where water may be used extensively for cleaning. Drains should be designed to be sealed when not in use or equipped with manual or automatic flushing systems.

Section 7.1 Plumbing, p.61

Guideline 42

All animal rooms and their anterooms should have a stainless steel, hands-free sink, preferably near the door.

Section 7.1.2 Plumbing for Animal Rooms, p.62

Guideline 43

All electrical outlets in animal rooms, and in other areas where they may be exposed to water, must have a ground fault interrupter (GFI) and be fitted with an all-weather cover.

Section 7.2.1 Electrical Outlets, p.64

Guideline 44

An emergency power source must be available to support life-sustaining equipment in all facilities holding animals.

Section 7.2.5 Emergency Power, p.65

8. ENVIRONMENTAL MONITORING AND CONTROL

Guideline 45

Each animal room should be equipped to monitor temperature, relative humidity, and differential pressures.

p.66

Guideline 46

Equipment and activities that generate noise and vibration should be isolated from the rest of the animal facility.

Section 8.1 Sound and Vibration, p.66

Guideline 47

Sound-reducing features should be incorporated into the building structure.

Section 8.1 Sound and Vibration, p.67

Guideline 48

The light intensity for animal rooms should be suited to the species that will be housed.

Section 8.2.1 Photo-Intensity, p.67

Guideline 49

Diurnal light cycles in animal rooms, including the crepuscular periods of dawn and dusk, should be controlled and monitored centrally, with alarms linked to the building automation system.

Section 8.2.2 Photoperiod, *p.68*

Guideline 50

The wavelength of light should simulate the natural wavelengths of sunlight as closely as possible.

Section 8.2.3 Spectral Quality, p.68

Guideline 51

HVAC systems should provide a healthy and comfortable environment for the animals and for personnel working in the facility and should be stable, so that the system does not contribute significantly to experimental variability.

Section 8.3 Heating, Ventilation, and Air Conditioning, p.70

Guideline 52

HVAC systems in laboratory animal facilities must operate continuously, 24 hours per day, year-round.

Section 8.3 Heating, Ventilation, and Air Conditioning, p.70

Guideline 53

The temperature of each animal room should be controlled separately in a manner that minimizes fluctuations.

Section 8.3.1 Temperature, p.71

Guideline 54

Relative humidity should be maintained between 40% and 60% and controlled to ± 5%, depending on the species in the animal room.

Section 8.3.2 Relative Humidity, p.71

Guideline 55

Animal facilities should be supplied with 100% clean air that is sourced from outside of the building. There should be no cross-contamination of incoming air with exhaust air, and air should not be recirculated within the facility.

Section 8.3.3 Air Intake, p.72

Guideline 56

Air must be exhausted efficiently so that the contaminants in the facility environment do not accumulate beyond acceptable levels.

Section 8.3.4 Air Exhaust, p.72

Guideline 57

Institutions must ensure clean air is available to all animals and personnel at all times.

Section 8.3.5 Air Quality, p.73

Guideline 58

Differential pressures between areas of an animal facility should be set so that air flow from one area to another reduces the potential for cross-contamination.

Section 8.3.7 Differential Pressure, p.74

9. AIR QUALITY PERFORMANCE-BASED STANDARDS

Guideline 59

Institutions that operate at less than 15-20 air changes per hour must monitor and record air quality contaminants and ensure a mechanism is in place to correct deviations from the performance standards.

p.80

Guideline 60

The key contaminants that should be monitored and documented to assure acceptable air quality are ammonia, carbon dioxide, particulate matter, and total volatile organic compounds.

Section 9.3 Key Contaminants and Target Values, p.83

Guideline 61

Ammonia levels must be maintained below 25 ppm and, in general, should not exceed 5 ppm.

Section 9.3.1 Ammonia, p.85

Guideline 62

Increases in room carbon dioxide levels should be kept below 500 ppm.

Section 9.3.2 Carbon Dioxide, p.86

Guideline 63

The increase in particulate levels above supply air levels should be kept below 12.0 µg/m³ or 35.3 million particles/m³ (1 million particles/ft³) as measured with an optical particle counter's 0.3 µm channel.

Section 9.3.3 Particulate Matter, p.86

Guideline 64

The increase in room total volatile organic compounds levels above supply air levels should be kept below 500 µg/m³ or 200 ppb, as measured with a photoionization-detector-based total volatile organic compounds instrument.

Section 9.3.4 Total Volatile Organic Compounds, p.87

10. SAFETY, SECURITY, AND REDUNDANCY

Guideline 65

All required safety equipment must be installed to meet all applicable safety regulations without compromising the functionality of the laboratory animal facility.

Section 10.1 Safety Equipment, p.92

Guideline 66

Security systems that limit access to authorized individuals only must be in place.

Section 10.3 Security System, p.93

Guideline 67

Facilities must be designed with sufficient redundancy to provide critical functions and services, including adequate air changes and maintenance of differential pressures, during mechanical breakdowns and power outages.

Section 10.4 Redundancy, p.93

1 INTRODUCTION

Throughout this document, the term 'should' is used to indicate an obligation, for which any exceptions must be justified to, and approved by, an animal care committee. The term 'must' is used for mandatory requirements.

Guideline 1

Facilities for animals used in scientific activities must be conducive to the welfare and safety of the animals, facilitate optimal animal care practice, provide an appropriately appointed and safe workplace for personnel, and, in the case of research and testing, establish a stable environment that will contribute to the reproducibility of studies.

The *CCAC guidelines: Laboratory animal facilities* is intended to assist both designers and users of laboratory animal facilities to achieve the above-stated objectives. The goal is to promote optimal animal care and facilitate animal-based activities without curtailing new and innovative ideas for facility design.

Animal welfare is a concept used to characterize the state of an individual animal and how this animal is experiencing the conditions in which it lives (CCAC, 2021). The *CCAC guidelines: Animal welfare assessment* (CCAC, 2021) focuses on affective states (Duncan, 2006; Brydges and Braithwaite, 2008; Dawkins, 2008; Mendl et al., 2009), with the aim of minimizing exposure to environments and stimuli that contribute to negative states (e.g., pain, fear, and frustration) and providing the opportunity for behaviour associated with positive affective states. For more details, see the *CCAC guidelines: Animal welfare assessment* (CCAC, 2021).

Experimental results are, in principle, only valid for the conditions under which they were obtained and only useful for comparison if all relevant information concerning experimental conditions is made available. The unequivocal imperative for valid, repeatable research and testing using laboratory animals sets significant demands on the architecture and mechanical engineering required to create an acceptable animal environment.

The *CCAC guidelines: Laboratory animal facilities* applies to all animals held in controlled laboratory environments. Where animals are to be temporarily moved for less than 12 hours to a procedure room for a particular scientific activity, the requirements may differ from the animal housing area; however, in all cases, the welfare of the animals must be assured.

These guidelines are not intended for animals in field settings. However, many of the general principles described within this document are applicable to most species maintained in captive environments for scientific purposes. Farm animal facilities, aquatic facilities, and facilities for short-term holding of captive wildlife are described in other CCAC guidelines (*CCAC guidelines on: the care and use of farm animals in research, teaching and testing* (2009), *CCAC guidelines on: the care and use of fish in research, teaching and*

testing (2005), *CCAC guidelines: Zebrafish and other small, warm-water laboratory fish* (2020), and *CCAC guidelines: Wildlife* (2023).

Designers and users of laboratory animal facilities must meet all relevant federal, provincial or territorial, and local regulations, codes, etc. These guidelines do not attempt to address building codes or safety codes and standards. It is the responsibility of consultant architects and engineers to address these matters in concert with the responsible institutional officials. In the planning and design of biosafety containment facilities, the *CCAC guidelines: Laboratory animal facilities* must be used in conjunction with current biosafety standards, such as the *Canadian Biosafety Standard* (Government of Canada, 2022) and the *Canadian Biosafety Handbook* (Government of Canada, 2016). The *Canadian Biosafety Standard* must be implemented whenever facilities will be used to house animals that are experimentally infected with human or animal pathogens. The *CCAC guidelines: Laboratory animal facilities* refers to barrier systems for minimizing cross-contamination since these are important concepts in all animal facilities. Barriers are commonly used to separate animals of different or unknown disease statuses and to protect animals from pathogens in the external environment. Where conflicts arise between CCAC guidelines and federal, provincial or territorial, or local regulations, codes, or standards, those regulations, codes, or standards take precedence.

Laboratory animal allergy is a major concern for the occupational health and safety of those exposed to laboratory animals (Wolfle and Bush, 2001). Exposure to laboratory animal allergens by persons outside the animal facilities, who are unaware of exposure, is particularly serious, especially in health-care settings.

These guidelines describe the standards for Canadian laboratory animal facilities. They are intended to be used as the basis for designing effective and functional laboratory animal facilities when establishing new facilities or renovating existing ones. Meeting these standards should ensure the availability of facilities necessary to maintain appropriate standards for animal-based science. Implementation of these guidelines requires all individuals involved with laboratory animals to be committed to exemplary practice in meeting the scientific and humane imperatives of animal-based science. Commissioning prior to use is an essential phase for both renovation of existing facilities and construction of new facilities (see Section 4.2, "Commissioning").

2 PLANNING AND DESIGN

Guideline 2

Construction and renovation of laboratory animal facilities must involve: 1) extensive planning by a project team that includes end-users, animal facility operations experts, veterinary experts, and engineers or architectural consultants; 2) veterinary authority to ensure animal welfare is a priority; and 3) commissioning of the project from start to finish for quality control.

Animal facilities built to appropriate architectural and engineering standards are expensive to build and maintain, and every effort must be made to ensure that planning and design are not flawed. Planning and design require the input of many people and the professionally guided acquisition and integration of the information that will drive the programming, design, construction, and commissioning phases. The collective outcome must promote animal welfare, provide a stable research environment, and facilitate optimal animal care practices. The finished structure should reflect both present and, as much as possible, future needs of scientific projects within the facility. Where there is the possibility of industry partners requiring space within the facility, their particular needs should be considered. In addition, the structure should be integrated into a cohesive design in which animal care personnel and physical plant maintenance personnel can perform their duties efficiently and effectively.

A comprehensive plan must be developed and form the basis of instructions and guidelines for the architect and engineer to develop detailed designs. The following sections outline the information that must be acquired (Section 2.1.1, "Information Required"), the people who should be involved in the process (Section 2.1.2, "Personnel Involved in the Planning Process"), potential means of acquiring information (Section 2.1.3, "Information Gathering"), and integration of the information (Section 2.1.4, "Integrating the Program").

2.1 PLANNING

2.1.1 Information Required

2.1.1.1 Fundamental Information

The following fundamentals must be completed:

a) Institutional and animal use program master plan: Develop a clear mission statement (purpose), define the goals and objectives of the project, and determine the location. The goals and objectives must be fully supported by the senior administration.

b) Functional programming: Define the functions required to meet the goals and objectives, and include the number and type of personnel, number and species of animals, types of animal housing, specialized

equipment, and biological, chemical, and hazardous agents required. The functions must be defined and prioritized by experienced scientific and technical personnel, under the direction of senior management, to ensure the project is cost-effective. Future requirements must also be addressed so that the facility has adequate space for a reasonable number of years.

c) Identify all criteria that may have an impact on the project (budget, regulations, guidelines, by-laws, etc.).

d) Identify the information technology requirements for integrated and seamless operations.

2.1.1.2 Estimate of the Size and Scope of Project

Estimating the size and scope of the project requires the following:

a) Develop a schematic design with costing. Define the net space requirements needed to accommodate the present and future functions (including services and equipment) and occupants. Space requirements should be defined by experienced planners and should be tested by comparisons to similar existing functional use spaces to ensure adequacy and efficiency. This also applies to services and equipment.

b) Develop detailed space data sheets that include the design requirements for each identified space. This information includes:

- functional description
- dimension requirements (including sufficient space to accommodate the replacement of large equipment, such as a cage washer, when needed)
- finishes and hardware
- furniture
- plumbing, heating, ventilation, and air conditioning
- lighting, power, and communication, with servicing access that involves no or minimal disturbance to animals
- safety elements, including allergen control
- equipment and accessories
- storage

c) Define required functional adjacencies by graphically linking the various components of the animal facility together.

For new or renovated facilities where only a few protocol authors will be involved, each of whom has predictable and fairly constant needs, it is relatively straightforward to determine the type of animal rooms, ancillary spaces, and total area required. As the numbers of these individuals increase, the complexity of programming increases exponentially, and estimating the size and scope of an animal facility solely on the basis of individually perceived needs can lead to large overestimations, especially if needs fluctuate. In addition, the growth of the institution and the needs of any investigators who will be recruited in the future must be considered. Experience with scientific requirements is important to be able to identify items that are not feasible or necessary and find opportunities to eliminate duplication and combine services. Appendix A, "Examples of Detailed Space Descriptions", illustrates how the information collected (see Section 2.1.3, "Information Gathering") can be used to estimate the size and scope of the project.

2.1.1.3 Associated Documents

The following actions should be taken with regard to documentation:

a) Coordinate and document the definitions and information in a report that can be used to develop a preliminary schedule and cost estimate, which can also be used to inform the senior administration and funding agencies.

b) Develop a budget with documents detailing the various stages of construction, costing, and construction and owner contingencies.

c) Identify the stage in the project where changes cannot be made due to the added cost of changing orders.

d) Outline the construction delivery method with consideration of the pros and cons of modular build, design bid build, design build, integrated project delivery, contractor at risk or fixed-price contracts, public-private partnerships, and a combination of these elements.

e) Develop documents for contractor bidding.

2.1.2 Personnel Involved in the Planning Process

The composition of the planning team should be in line with the size and scope of the project; however, the team should include expertise and experience in all the areas identified above. At least one key person from this team (preferably an end-user) should continue as a participant in all the other stages (design, construction, and commissioning) to maintain continuity.

The following individuals should be consulted and, in most cases, play an active role in the planning phase:

a) Senior administrators directly involved with the project: control the budget and make all major financial decisions; they are involved in prioritization throughout the institution and know the animal facility's status in this context.

b) Institutional directors of planning and facilities: oversee the emerging need for compatibility with institutional policies and objectives as the program develops; they will retain the appropriate architectural and engineering consultants for the project. The planning office will usually convene all fact-finding activities from the very beginning.

c) Scientific personnel and scientific technical personnel: those working with or who will be working with animals.

d) Department heads or study directors: those who will have an overall view of the direction and emphasis of the animal-based science programs and of future needs.

e) The facility director: the principal advisor on compliance with animal care and use guidelines and regulations and laboratory animal science issues, and as the principal manager of the facility and the personnel who will operate it.

f) Laboratory animal veterinarians: responsible for the application of sound principles of laboratory animal science and medicine.

g) Laboratory animal technicians: responsible for operating the proposed new facility; they will have invaluable input into appropriate ergonomics and equipment utilization.

h) Plant maintenance supervisors: responsible on-site for keeping the facility fully operational, electrically and mechanically.

i) Occupational health and safety advisors and compliance officers: for biosafety, radiation safety, etc.; the criteria for safety guidelines should be present from the very beginning.

j) Security officer: individual who is familiar with the institutional security requirements and the unique requirements of animal facilities.

The services of a programmer (architect or engineer) experienced with current animal care requirements should be sought at the programming stage unless the project is relatively simple. Animal care facilities are not common, and the regulations and technology change rapidly.

If the institution has knowledgeable personnel who are experienced with the design process, consultants without expertise in this area, particularly those who have extensive medical or research facility experience, may be engaged and educated to understand the specific requirements of animal care facilities. Whether using the services of a consultant or in-house expertise, the planning team should challenge all preconceived notions and examine alternative approaches to providing the most effective program criteria. The shared information and experience of other institutions is also valuable.

2.1.3 Information Gathering

All relevant information should be collected through interviews and focus groups, knowledge of the current facility, and new information that has become available.

2.1.3.1 Interviews and Focus Groups

Institutional representatives such as the director of laboratory animal resources and key managers, together with the director of planning or a designate, should meet with all protocol authors to determine the current and future needs. A similar meeting should occur with the compliance and safety officers and physical plant supervisors. The programming consultant should be familiar with the goals of the interviews and facilitate this stage of the process.

Interviews with protocol authors and their respective teams are critical for extracting data relevant to project size and scope and for determining physical support for optimal performance. The current numbers of animals, rooms, cage types, etc. should be available from the current inventory, and future projections can be sought by verbal communication and written forms. However, it is important to obtain additional information from the respective individuals and teams about their work. During the interviews, the following questions may assist in eliciting productive discussion:

- What does your work involve?
- Where do animals fit into the overall objectives of your work? Will the level of animal-based activities increase or decrease?
- What physical activities do you perform in relation to your animal-based work? How might your work be better facilitated?
- In which places do you currently perform the work? What are the pros and cons of these areas?
- What movement of personnel and animals is involved?

As the questions are addressed, discussion should be encouraged on current concerns, problems, and improvements. The discussions should be of a brainstorming format. All information is relevant and needs to be recorded, even when it does not appear to have an immediate impact. For example, a casual statement

by an investigator that old silos had proven valuable for creating simulated natural environments for certain critical wildlife experiments could provide the foundation for designing a simulated natural environment suite with the necessary features of the old silo, along with essential features to meet contemporary standards.

2.1.3.2 Existing Information

Where animal-based projects are ongoing, information should be available to establish the current size and scope of the operation. For example, answers to the following questions should be available:

- How many animals of each species are held at one time (maximum)?
- How many animals of each of these species are specific-pathogen-free, viral-antibody-free, conventional, etc.?
- How many animals and of what type are maintained in Containment Level 2 and Containment Level 3 at one time?
- What types of barriers are currently being used?
- How are the animals in each particular situation housed (singly, in pairs, triads, groups of four, etc.)?

From this information, the types and numbers of enclosures can be estimated. It is then possible to estimate the number and type of cage racks, pens, tanks, and runs needed in the different zones of the animal facility (biocontainment, disease-free rodent barrier area, specific-pathogen-free beagles, etc.).

Decisions related to the degree of separation of groups of animals are among the most difficult. For example, in older facilities, several investigators may share a mouse room. Investigators and veterinarians should be asked how they view this situation. In addition, laboratory animal technicians should be asked how they see this working in relation to their obligations to each investigator. Consideration should be given to whether a number of small spaces are more or less valuable to the program than fewer larger rooms, and whether adequate sequestration in larger rooms can be accommodated by individually ventilated cage systems.

All guidelines, codes, and regulations that may affect the design of the laboratory animal facility must be identified, and the program team must become familiar with their application. This includes criteria for accessibility, as stipulated in provincial or territorial and municipal regulations.

2.1.3.3 Incorporating New Ideas

Planning a new facility should include evaluation of: 1) how each facet of the operation aligns with current knowledge in epidemiology and disease control, environmental factors, housing methods, and environmental enrichment; and 2) any changes in hygiene standards, safety standards for working with hazardous substances (e.g., radiation), and biocontainment requirements.

2.1.3.4 Operation and Management Information

2.1.3.4.1 The Animal Room Layout

The layout of the animal rooms, particularly where individually ventilated cages are involved, is an important part of the planning and design process. This requires particular attention to the effective movement of animal care personnel, equipment, and various research personnel working in the room.

Individually ventilated cages enable large numbers of rodents (particularly mice) to be housed within an animal room. To take full advantage of the biosecurity afforded by individually ventilated cages, cage changes and animal manipulations should take place in biosafety cabinets or in mobile cage stations with biosafety cabinet equivalency that are manufactured specifically for the purpose. Where the number of individually ventilated cages in the room is high, mobile change stations must be used for efficiency and practicality. Since double-sided biosafety cabinet units tend to be integral to the effective utilization of space, the circulation patterns of personnel and mobile equipment require careful attention.

In larger animal rooms, great care should be taken to ensure that the servicing of the animal room by animal care personnel does not conflict with the activities of the investigator's team. The layout should enable animal care activities to be performed efficiently and provide separate space for manipulations performed by research teams. This may require specialized equipment such as biosafety cabinets or procedure hoods to be duplicated in rooms.

2.1.3.4.2 Ergonomic and Accessibility Considerations

A clear understanding of the ergonomics of the general operation and maintenance of the animal facility is essential, along with knowledge of the equipment that is available to address the challenges. Many tasks in animal facilities can be physically demanding, expose workers to allergens, or create the potential for work-related injury; examples of these include moving bags of food and bedding, cage cleaning, and accessing cages on high or low shelves (see Section 10.2, "Safety of Personnel").

Other factors affecting personnel, such as gender diversity and barrier-free physical access, are also important considerations; for example, gender neutral or inclusive washrooms, and wheelchair access.

2.1.3.4.3 Management Decisions

The management of a facility contributes important criteria that should be considered in the design. For example, if different personnel will be working on the clean and dirty sides of the cage washer, the area may be designed so it is not cumbersome to pass between the two sides. However, if it is known that one person will be working in both areas, a clothes-changing station and possibly a shower should be built between the two areas. Assuming all of the information regarding the potential use of the facility has been collected, it should be possible to make some management decisions that will have a significant impact on the design of the facility.

Management criteria that may influence facility design include:

- Number, role, and experience of personnel in the facility (e.g., investigators, teachers, study directors, veterinarians, animal care personnel, and facility personnel) – influences decisions concerning security, voluntary versus forced barriers, lighting requirements, and arrangement of rooms and corridors to facilitate work.
- Numbers and types of animals held – influences decisions concerning the number of animal rooms, types of barriers, and air pressure control.
- Procedures conducted and services offered – influences decisions concerning the number and type of procedure rooms (e.g., necropsy and surgery).

2.1.3.4.4 Modelling or Mock-Ups

The use of life-size mock-ups is advisable to examine the ergonomics of the animal facility, particularly the animal rooms. This does not necessarily require the actual apparatus, but the dimensions must be precise to enable personnel to act out the physical aspects of the various tasks within a given space. Personnel location, task interaction, and traffic flow can be much better understood and planned for when realistic scenarios are attempted. The interaction of personnel in this process is essential.

2.1.4 Integrating the Program

2.1.4.1 Detailed Space Data Sheets

Following the clear identification of needs, as outlined above, the next step is the preparation of detailed space data sheets combined with space relationship diagrams. This is often referred to as a detailed space program. It should also take into consideration budget constraints.

The information collected, as described in Section 2.1.3, "Information Gathering", is used to identify the types and sizes of spaces required. This information is combined with the criteria (Section 2.1.1, "Information Required") to develop detailed space data sheets that outline essential requirements for each space (see Appendix A, "Examples of Detailed Space Descriptions").

2.1.4.2 Functional Relationships

In addition to the detailed space data sheets, all required functional relationships and traffic flow patterns between the various spaces must be identified. For example, the dirty side of a cage wash area should be located such that there is good access to a loading dock for waste disposal.

2.1.4.3 Budget

Once the previous stages have been completed, it should be possible to derive a fairly accurate estimate for the cost of construction of the proposed facility. For this, the services of a professional cost consultant (quantity surveyor) may be required. The program must be well prepared to meet the needs as closely as possible within budget constraints, as changes are more costly further into the design and construction stages.

The funds committed in the planning phase should be converted into a budget, with line items for elements that should be incorporated into the program.

The total project cost is the sum of the following items and makes up the capital funding budget.

a) Design fees: all costs involved in the design process, which include architectural and engineering planning, drawings, etc. This may also include the cost of programming if it is under the same consultant; however, it is common to hire one consultant for programming and a different one for design, in which case, the programming fee is distinct from the design fee.

b) Administration fees: the funds necessary for project management (from beginning to end) and commissioning of surveys, soil testing, fluid dynamic studies of air movement in building clusters, etc.

c) Construction costs: the major part is the costs to construct the physical structure, including mechanical and electrical systems; however, other construction costs should also be noted.

d) Equipment:
   - fixed – whether cage washers, autoclaves, etc. are included in the construction costs should be clarified at an early stage
   - movable – cage racks, carts, steam cleaners, pens, etc.
   - furniture – benches, cupboards, desks, etc.
   - miscellaneous – items not covered in the above three categories (e.g., an electric tractor for pulling flat carts loaded with cages or closed-circuit television for the genetically modified animal suite)

   Variability exists among facilities, and it is very important to know how each of the above categories is to be funded.

e) Commissioning costs: the funds required by the institution to ensure the construction is done according to plan throughout the construction phase and at the end, to get the facility up and running; this can be quite demanding with animal facilities.

f) Moving and decanting costs: moving-in costs occur in all types of projects, but the situation is more complicated where large numbers of animals of varying status have to be moved. These animals could be particularly vulnerable colonies, such as virus-antibody-free, inbred, genetically modified mice, or specific-pathogen-free beagles in a long-term reproduction study. The movement of these types of animals must be carried out with extreme care. Moving animals is very labour intensive, time-consuming, and expensive, and may require special equipment.

   Decanting is the byproduct of renovation. Prior to renovating, all animals and functions have to be moved elsewhere and then moved back again when the renovation is complete. This requires standard operating procedures (SOPs) for transport and suitable temporary quarters, such as trailers, or agreements or contracts if animals are to be moved to another institution. In all cases, CCAC standards for daily care, veterinary care, post-approval monitoring, training, etc. still apply. When comparing total project costs for renovation versus new construction, decanting costs may be a significant factor. In certain circumstances, new construction, although it may have a higher per-square-metre cost compared to renovation, may be substantially less expensive by the time double decanting and temporary accommodation costs are included in the total budget. New construction also generally provides better space that can be used over a longer period.

g) Contingencies:
   - estimation contingencies
   - construction contingencies

   There are inevitably unforeseen elements in both of these types of contingencies, and funds should be reserved to deal with them as they arise so that the project is not compromised.

h) Escalation: construction costs are subject to inflation, and the time lag between the onset of a project and its completion may be several years, depending upon the size and urgency. Thus, the cost estimate for the proposed building is prepared at current prices and an escalator or inflation factor is used to estimate what the proposed costs will be when the competing contractors submit their bids, and the price is finally fixed.

i) Value-added taxes: taxes such as the Canadian Goods and Service Tax (GST) must be taken into account.

j) Financing costs and investment income: if money has to be borrowed, this has a negative impact. If money is received upfront, accrued interest until expenditure can enhance the value. This factor may be substantial.

2.1.4.4 Operating Costs

Although the operating costs are not usually part of the capital funding budget, they are important criteria that must be considered to prevent the construction of an animal facility that is not financially viable. Considering the useful life of a new animal facility, it should be estimated that approximately 15-20% of the total costs to build and operate that facility will be for design and construction, while 80-85% will be for its operation.

All aspects, such as utility costs to maintain environmental control, mechanical maintenance (e.g., filter changes), personnel costs to manage the facility properly within appropriate operating procedures, costs to maintain surfaces and equipment, and waste management costs, should be identified and estimated upfront. It should be recognized that the manner in which individual elements will ultimately be used and operated will have a major financial impact on the yearly operational costs.

2.2 DESIGN

Some of the main factors that influence design are:

- regulations and guidelines
- current and emerging best practices in animal welfare
- animal models (single-species or multi-species)
- spaces (basic components) and functional adjacencies, efficiencies, and net space
- the need for conventional, bioinclusion, or bioexclusion barriers
- biosafety level requirements (Animal Biosafety Level 2, 3, and 4, as per the *Canadian Biosafety Standard* (Government of Canada, 2022))
- biosecurity
- circulation (traffic flow)
- sound, lighting, and vibration
- energy requirements and surge capacity
- flexibility to meet current needs, e.g., flexibility for species (including opportunities for refinement), integrated imaging, integrated behavioural suites, and surge space for specialized laboratories
- operational costs
- flexibility to accommodate future needs over the life of the facility

2.2.1 Conceptual Design

Once the program is complete, the architect and engineer should draw sketches to show the relative positions of the various spaces. The architect and engineer should be responsible for the design, in order to take advantage of the experience of these professionals. They will often come up with designs and solutions that

were not previously considered and may be far superior. Changes to the design before construction may be requested, but these should not constrain the ingenuity of the design team. The initial conceptual sketches may be fairly rough diagrams, and these are developed and changed until they best meet the criteria for functional adjacencies and traffic flow patterns. There may also be other criteria that need to be considered in the conceptual design, such as site restrictions, existing facilities, and mechanical services.

2.2.2 Preliminary Floor Plans

The conceptual design that best meets the program requirements is then turned into a preliminary floor plan, such as that illustrated in Diagram 1. During this stage of design, the space sizes projected in the functional program become relevant and are incorporated, where possible, into the preliminary floor plan. Various components of the animal facility such as the cage wash area, surgical suite, and suite of animal rooms, are often designed separately and then incorporated into the overall floor plan.

2.2.3 Graphic Test

When the design team believes they have a reasonable floor plan, it should undergo a graphic test. The design should pass this test before progressing to the next stage. This test involves evaluating the functionality of the design, and the following questions should be asked:

- Are the traffic flow patterns correct, and can they be controlled as required?
- Can corridors, doorways, anterooms, etc. accommodate the people and equipment that will be passing through them? (Scale models of cage racks and other equipment should be cut out of paper and moved through the floor plan as they will after construction.)
- Are the door swings logical and functional? Are doors and rooms designed to optimize the space available?
- Are barriers located in appropriate locations, and can they be changed to alter the size of barrier areas (flexible barriers)?
- Are sinks properly positioned in rooms and anterooms?
- Can the mechanical systems be accommodated so that they are accessible for servicing?
- Is equipment that is likely to produce ultrasounds or vibration, such as elevators, located away from animal rooms?
- Are offices and the reception area positioned to control entry into the animal facility?
- Is the design such that future expansion can be accommodated?

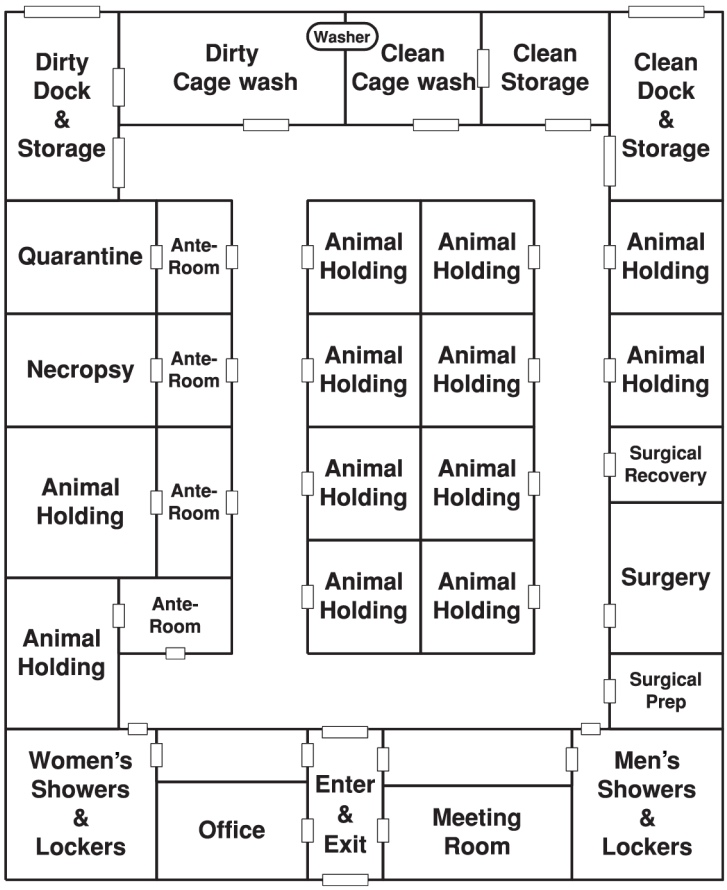


Diagram 1 Preliminary floor plan

2.2.4 Mechanical Systems

Consideration should be given to how the mechanical systems will fit into the overall design. Mechanical systems require considerable space, especially when one considers the need for redundancy. These systems should also be accessible for servicing (e.g., all high-efficiency particulate air (HEPA) filter units must be recertified at least annually), preferably from outside the facility but at least from outside animal areas. Containment facilities must be serviced from outside the containment barrier (see Government of Canada, 2022). It is prudent to develop a mock-up model of an animal room to check the airflow distribution by the proposed heating, ventilation, and air conditioning (HVAC) system and to determine whether the position of the air intake and exhaust provides a good distribution of air when racks and cages are present. If not, the system should be redesigned before building it into the entire facility.

2.2.5 Detailed Design

Once the graphic tests have met the required criteria and the mechanical systems have been checked for effectiveness, the final blueprints are developed, incorporating all the details of the program. It is important that care be taken in developing these detailed designs since changes beyond this stage can be extremely costly.

3 LOCATION

The choice of site for an animal facility is extremely important and requires careful consideration. Even when animal facilities are in existence, it may be more practical and economical to build a new facility in another location than to upgrade an existing facility. It can be very difficult, and occasionally impossible, to incorporate the sophisticated mechanical requirements and necessary traffic flow patterns into existing structures.

The chosen location must also have sufficient space available on-site to meet the requirements during construction (space to accommodate the equipment, building materials, field office, waste containers, machinery, parking space for construction workers, etc.).

Guideline 3

Laboratory animal facilities must be located in areas with reliable access to water, power (electricity, gas, steam, or another suitable source), and sewage disposal.

Animal facilities must have the capacity to maintain environmental conditions as required, 24 hours per day, all year round. There should be access to public utilities, such as water, gas, electricity, and sewage disposal. These services must be reliable and backup plans must be in place in case of an emergency where such services are lost. Consideration should also be given to environmental variables (e.g., temperature and humidity) at the location, as these could potentially impact the size and function of integral components such as the HVAC system and humidifiers.

Guideline 4

The location of laboratory animal facilities should ensure access to clean air and should ensure that exhaust air does not enter the facility or other buildings.

The location of the animal facility within a larger building, or its location relative to surrounding buildings (existing or proposed), needs to be carefully studied. There must be a good source of clean air (see Section 8.3.3, "Air Intake", for a definition of clean air and information on filtering incoming air). It must be possible to exhaust equivalent amounts of air without contaminating the air intakes of other units. Care should be taken to ensure that the air intake of the animal facility is not contaminated by its own exhaust air via the building air envelope.

To address the impact of adjacent buildings on the animal facility's air supply and exhaust, the fluid dynamics of the building mass and clustering under differing atmospheric conditions should be defined. This may be achieved using computational fluid dynamics. In some circumstances, it may also be necessary to perform wind tunnel studies to predict performance. Relative to the cost of design and construction of an animal facility, the cost of fluid dynamics studies is modest.

Guideline 5

The location of laboratory animal facilities should facilitate the receipt of animals and supplies, and facilitate the removal of wastes.

Direct access to the outside for deliveries and waste disposal is desirable. Facilities that are located on upper floors of a building should be serviced by a minimum of two elevators, with access limited to facility purposes as much as possible. In situations where an elevator will not be for the sole use of the animal facility, there should be an override system to prevent access from other floors during use.

Where elevators are required, the entrance to the elevator should be in a vestibule in order to buffer the changes in differential air pressures created by the movement of the elevator in the shaft. It may also be possible to design the elevator shafts to reduce or eliminate this problem (e.g., a loop system).

Guideline 6

For biosecurity and safety reasons, the location of laboratory animal facilities should preclude public access and the need for movement of animals and cages through public areas.

Facilities should be readily accessible to personnel, yet easily secured. The location of the facilities should ensure sufficient space is available to enable routine and experimental procedures to be conducted within the confines of the laboratory animal facility, to reduce the need to transfer animals to and from investigators' laboratories. The movement of animals outside the animal facility should be discouraged due to stress caused to the animals, effects on research, contamination hazards, and exposure of individuals outside the facility to laboratory animal allergens. Where it is not possible to incorporate research space within the animal facility, proximity to research laboratories is a very important consideration.

4 CONSTRUCTION AND COMMISSIONING

4.1 CONSTRUCTION

Where animals will be maintained in a facility during renovations, noise and vibration concerns and mitigation measures must be considered in all phases of the process.

At the construction stage, the most important job of the team overseeing the project is quality assurance. In addition to the architects and engineers, the team should include senior administrators directly involved with the project, at least one internal quality assurance person who will be working in the facility and is familiar with the construction requirements of an animal facility, and a person who will be directly involved with the animals (i.e., a member of a research, veterinary, or animal care team).

The oversight team should be provided with daily and weekly reviews from the construction team. The quality of materials used and the workmanship should be checked on a daily basis to ensure they meet the program requirements as specified. No substitution of materials should be permitted unless previously approved. All mechanical, electrical, and plumbing systems must meet equipment specifications, operate according to SOPs, and have sufficient redundancy.

If design errors occur, the earlier they are detected and corrected, the lower the additional costs. Detailed cost estimates of all changes should be provided by the construction company to the oversight team prior to initiating them, since they are not usually part of the original contract and may result in additional charges.

4.2 COMMISSIONING

Guideline 7

New and renovated facilities should undergo commissioning, with the commissioning agent reporting to the facility owner to ensure all program requirements are met prior to the introduction of animals.

Because of the complexity of laboratory animal facilities, the commissioning process should start during the design phase and continue throughout the project until a specified time after occupancy. Final acceptance of the newly constructed facility entails assurance that all architectural and engineering specifications have been met. This involves testing and validation of everything in the facility to ensure that it meets the program requirements. A detailed commissioning list should be made from the program and the detailed design, which should include at a minimum the testing and checking of features such as the resistance of floors and walls to chemicals; the temperature, humidity, and air distribution in each room; room air pressures; the functioning of redundant and emergency systems; and the temperature and cycles of cage washers and autoclaves. Commissioning should also include providing records of all warranties and extensions for materials and equipment.

Acceptance should not occur until all deficiencies have been corrected or an agreeable plan instituted to rectify them. It may be difficult to get construction companies to take responsibility for deficiencies that are discovered after occupancy, which can result in institutions having to spend considerable amounts of money to make the facility functional. Thorough commissioning during the construction phase and prior to final acceptance should alleviate many of these problems. The success of final commissioning is dependent on earlier confirmation that all design specifications are correct.

The commissioning process should be conducted by a company that is not involved in the construction of the facility. This can accelerate the timeline to completion and catch details that may otherwise be overlooked.

5 COMPONENTS OF A LABORATORY ANIMAL FACILITY

The purpose of a laboratory animal facility is to confine animals in comfortable, safe, stable environments that are conducive to the requirements of the scientific activities and promote good animal welfare by providing for the species-specific physiological, social, and behavioural requirements of animals. This requires consideration of the diverse needs of the different types of animals (species, strains, genetically modified, etc.) to be housed and the requirements of the scientific activities to be conducted. These animals often vary in their microbial background, and facilities must minimize the potential for cross-contamination through facility design and engineering and operational controls.

Guideline 8

The components of an animal facility should be organized to facilitate optimal care of the animals and enhance their welfare, enable scientific activities to be performed effectively and efficiently, and minimize biosecurity and safety risks.

A laboratory animal facility usually requires separate areas for specific functions, specialized rooms and equipment, closely controlled environments, a substantial amount of storage space, and a layout conducive to safe and effective operation. The components of the animal facility should be organized according to their functional relationships and efficient traffic flow as much as possible. For example, procedure rooms should be in close proximity to the animal rooms, and the movement of equipment should aim to minimize the potential for cross-contamination in a practical and effective manner. Anterooms greatly improve the segregation of animal rooms, as discussed in Section 5.7, "Barriers", and allow for effective bidirectional movement. The planning and design of animal facilities must consider the movement of animals and associated materials, and include an integrated overall plan that minimizes the need for such movement. It is also important to include proper signage to indicate how particular rooms or areas are being used.

5.1 ROOMS FOR ANIMALS AND PROCEDURES

5.1.1 Animal Rooms

Animal rooms include those rooms in which animals are housed on an ongoing basis and specialized rooms for the quarantine or isolation of animals when necessary. Where animals are to be temporarily moved to a procedure room for a particular scientific activity for less than 12 hours, the requirements may differ; however, in all cases, the welfare of the animals must be assured.

When designing animal rooms, it is important to be aware of current needs and possible future requirements (see Section 2, "Planning and Design"). In most animal facilities, needs fluctuate according to changes in the scientific personnel and projects. Versatile animal rooms facilitate rearrangement to accommodate changes in enclosures and ancillary equipment for housing different species and permit a variety of projects

to be undertaken over time. In addition, the ability to modify environmental parameters is often necessary to accommodate various scientific needs.

The use of anterooms for one or more animal rooms can result in less movement of animals, provide more space for the storage of equipment (including personal protective equipment), and provide an appropriate procedure area (especially when designed to hold a workstation or biological safety cabinet).

Guideline 9

A sufficient number of animal rooms should be available to house animals in a manner that maintains their health status, avoids negative influences from other animals, and minimizes disruption from human activity.

To limit the variables influencing scientific activities and reduce the potential for a widespread disease outbreak, animals should be separated according to species, health status, source, social compatibility, and feeding schedules. They may also need to be separated for individual projects. Where animals from different sources are to be housed in the same room, some degree of isolation can be achieved through specialized room design and equipment, such as ventilated racks with separate connections to the building ventilation system and pressurization, isolators, HEPA tents, controlled airflow cubicles, and portable laminar airflow units. Animals housed within a room should have similar environmental requirements (e.g., temperature and light cycle).

Separate rooms are required for quarantine and isolation of particular animals, including sick animals, immunodeficient and immunosuppressed animals, animals that have been removed from and then returned to the animal facility, imported animals, and animals involved in scientific activities using pathogens. Observation and isolation rooms may also be required for observation, conducting detailed health examinations, quarantine, acclimatization, and conditioning of newly acquired animals, especially random-source animals (e.g., random-source dogs, cats, rabbits, and wild animals).

Guideline 10

The size of an animal room should be determined by the species and number of animals to be housed, the size and type of housing required to address the animals' needs to perform important species-specific behaviours, the type of scientific activities, husbandry requirements, ergonomic requirements for personnel, and the services needed.

The relevant CCAC types of animal guidelines provide information on the types and sizes of enclosures needed for the particular species to be housed in the room.

The size and layout of individual animal rooms may be derived by applying the example of preliminary size estimation to a detailed space description. Examples of different animal room layouts are illustrated in Diagrams 2 to 5.

Additional space may be required to conduct procedures with no or very minor negative welfare impact; however, if the need for such space is anticipated, measures must be taken to minimize the potential impacts of the procedures on other animals in the room (see the CCAC's types of animal guidelines). Where animals

are held in ventilated racks, space may be required to install appropriate biosafety cabinets to permit such procedures to be performed in the room.

Where mobile change hoods are used, sufficient space must be available between racks to accommodate them. Sufficient space must also be available around ventilated cage racks to service them.

Animal rooms should be designed for ease of sanitation and access to visually inspect each animal daily. In addition, space is required to accommodate room-specific sanitation equipment. There should be a stainless steel, hands-free sink for hand washing located near the door or in an adjoining anteroom. Other suitable alternatives may exist to address biosecurity, cross-contamination, and allergen concerns.

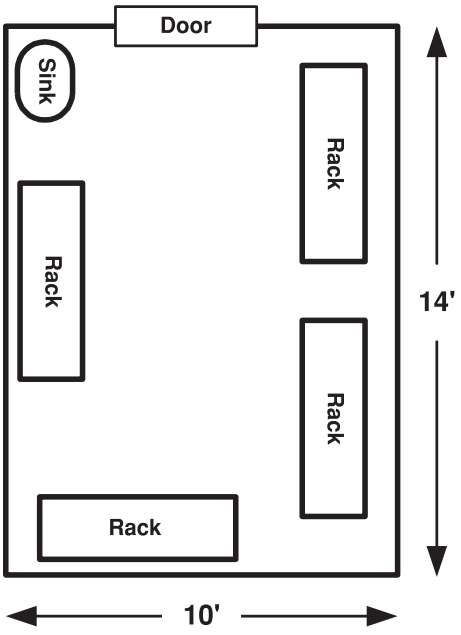


Diagram 2 **Conventional rodent room**

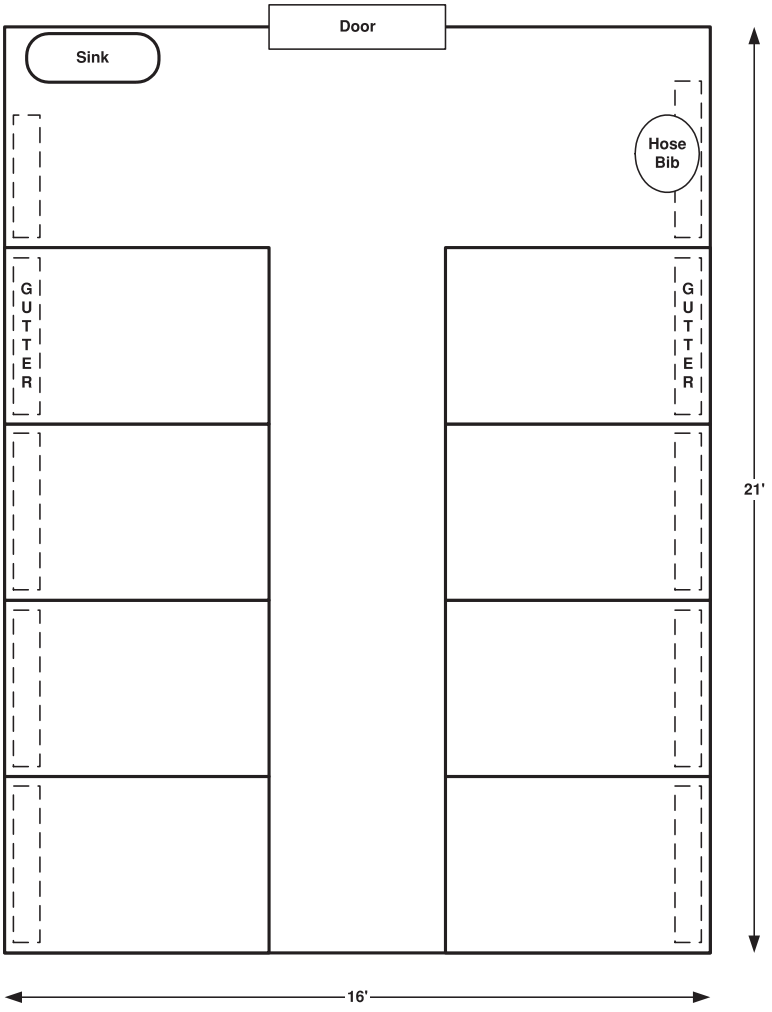


Diagram 3 **Conventional dog pen room**

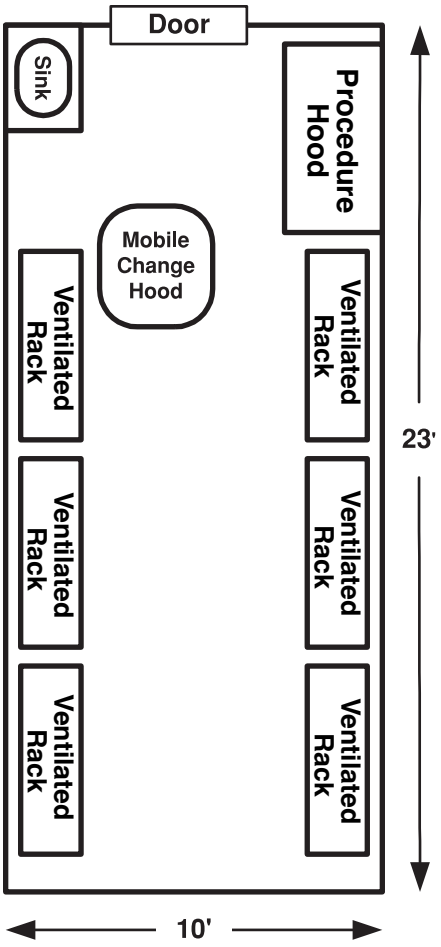


Diagram 4 **Rodent holding room with single-sided ventilated racks**

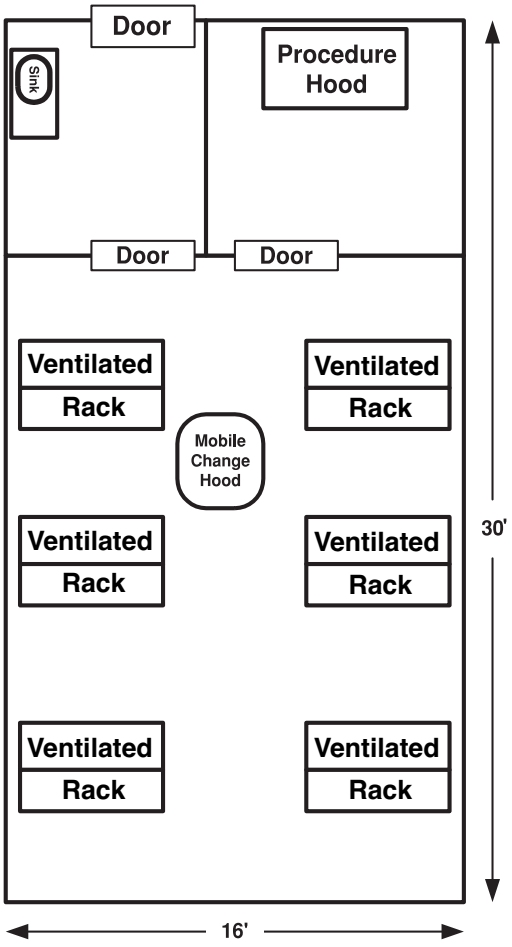


Diagram 5 **Rodent room with double-sided ventilated racks, entrance anteroom, and integral procedure room**

5.1.1.1 Functional Adjacencies for Animal Rooms

Each animal room should be located to facilitate all necessary activities efficiently and to minimize the risk of contamination between animals and humans or activities in other rooms (i.e., biocontainment).

Traffic flow patterns must be considered when deciding on the location of the animal rooms and their potential use. Animal rooms should be located so that there is relatively easy access to both the dirty side of the cage washer and clean cage storage. Rooms for animals with an unknown background (e.g., random-source animals) and isolation rooms for animals potentially infected with pathogens or of unknown pathogen status should be close to the dirty side of the cage washer and autoclave. Rooms for animals that are known to be free of infections and infestations should be located closer to the clean side of the cage washer.

Animal rooms that will be accessed frequently by investigators and other personnel who are based outside of the animal facility are often best located near the entry to the facility.

Where there is more than one loading dock, the quarantine rooms should be located near the dock designated for the movement of animals and materials that pose a risk for cross-contamination.

5.1.2 Procedure Rooms

Procedure rooms are needed for the conduct of procedures with negative welfare impact on the animal, procedures involving restraint (especially where wild animals are involved), and procedures with the potential to induce stress in other animals housed in the room.

Guideline 11

Well-appointed procedure rooms should be available within the animal facility to reduce the need to transport animals to laboratories located outside the facility.

The use of procedure rooms within animal facilities will reduce the introduction of non-experimental variables and improve the reproducibility of data, eliminate the impact on other animals within the room, and reduce the spread of potential allergens outside the facility. In addition, animals experience stress when moved to a new environment, and this can be compounded by the length of transport.

The number of procedure rooms should accommodate the number of investigators at the institution such that there are minimal wait times to use a room, and rooms should be designed with the flexibility to provide for current and future scientific needs. The number and design of procedure rooms should also aim to prevent alarm signals produced by distressed animals undergoing procedures from inducing stress in other animals.

Anterooms can provide useful procedure space dedicated to one (see Diagram 5) or more (see Diagram 6) animal rooms. Anterooms can greatly reduce or eliminate the need to transport animals along common corridors for procedures. However, sharing anterooms or procedure rooms among a number of different investigators increases the risk of introducing additional variables.

Animals undergoing procedures should be held in a distinct ventilated environment (Harrison, 2001), e.g., biosafety cabinets or fume hoods that are not used for chemicals. However, animals should never be housed in these units for longer than 12 hours, as the needs of the animals cannot be suitably met.

Guideline 12

A separate procedure room should be available for specialized equipment and for procedures that require minimal distraction.

Where the procedures that will be conducted require an array of equipment, such as physiological monitors and imaging equipment, there should be a separate procedure room. Procedure rooms are also used for tests that are sensitive to external distractions, such as behavioural tests and drug tests. These requirements

should be carefully enumerated during the planning stages, and procedure rooms should be located strategically with respect to the proposed animal rooms.

It is important to emphasize flexibility and adaptability in the design of procedure rooms since their use will inevitably fluctuate. The rooms must also be designed to facilitate frequent sanitation because of multiple use.

If animals may be held in procedure rooms for longer than 12 hours, the air quality and temperature controls for procedure rooms should be the same as for animal rooms in order to maintain animal health. There must be sufficient lighting to perform anticipated procedures and a substantial number of electrical outlets (see Section 7.2, "Electrical").

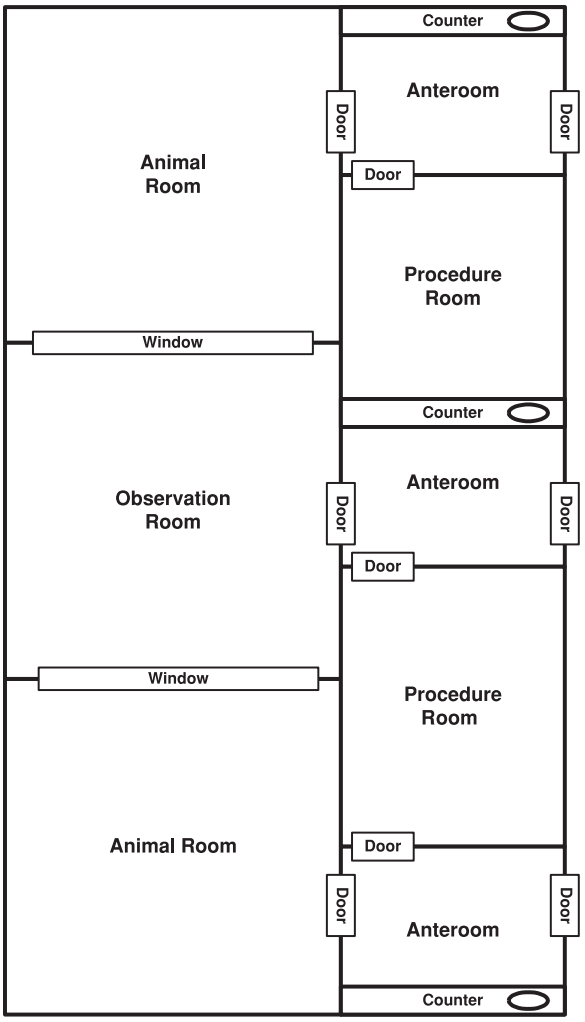


Diagram 6 Procedure anterooms

The type and quantity of cabinetry in procedure rooms depends upon the proposed use. Where the type of work will be fairly similar over a number of years (e.g., toxicology testing), specific cabinetry needs can be accommodated on a permanent basis. However, in a multi-faceted and variable research setting (e.g., a large university), consideration should be given to mobile tables, cupboards, shelves, etc. that are appropriate for intermittent specific needs and are readily sanitized.

5.1.2.1 Functional Adjacencies for Procedure Rooms

Procedure rooms should be adjacent to the respective animal rooms and can be incorporated into anterooms for one or several animal rooms, as previously discussed (see Diagram 6). If procedures are to be conducted in laboratories outside of the animal facility, these laboratories should be located as close as possible to the facility so that animals do not have to be transported long distances through routes of access shared by other institutional personnel or members of the public.

5.1.3 Surgical Suites

Guideline 13

Surgical suites must be designed to provide aseptic conditions that meet current veterinary standards.

Specific rooms for experimental animal surgery (i.e. a surgical suite) are a frequently required component of laboratory animal facilities, as investigators should not be permitted to transport animals to their own laboratories for surgical procedures. Specific surgical suites enable monitoring and post-surgical care of the animals by animal facility personnel and ensure adequate standards of sanitation.

As noted in the *CALAM Standards of Veterinary Care* (CALAM, 2020), surgical suites must meet provincial or territorial veterinary standards.

Appropriate space is required to accommodate the following principal functions of a well-appointed animal surgery:

- surgeon preparation and scrub
- animal preparation and premedication
- surgical operation, including anesthesia
- post-operative recovery
- intensive care
- equipment storage and servicing
- cleaning and sterilization of instruments (including surgical packs) and space for holding or storing surgical supplies

Planning the number of rooms and overall space requirements to accommodate these functions should be determined through consultation with the relevant scientific personnel, taking into consideration the species involved and procedures to be performed. These components can often be accommodated in a 4-area (room) space: an area to prepare the animals, an area to prepare the surgeon, the operating room, and a recovery area. Some of the auxiliary functions can be combined within one space, depending on the anticipated workload for the surgical suite. Where there is more than one operating room in the suite or higher use frequency, multifunctional ancillary rooms may be less useful.

Although an appropriate operating room should be available for all animal surgery, when it is minor surgical procedures in small rodents, a specifically designated area of the animal room that eliminates visual,

olfactory, and auditory cues may suffice, if approved by the animal care committee. In such cases, a Type II biosafety cabinet or a portable laminar flow unit must be used so that a constant stream of sterile air can be provided.

Other considerations for surgery include the need for areas for laundry services, centralized service consoles for gases and power, emergency power, and specialized scrub sinks. If gases are to be piped in, it is preferable that space be allocated near the loading docks for holding gas cylinders (including spares) rather than in the surgical suite, as they represent a biohazard. Irrespective of their location, gas cylinders must be carefully secured.

Internal windows should be incorporated into surgical suites to increase visibility from one part of the suite to another and maximize visual communication. Internal windows are particularly useful when circulating personnel are required to oversee multiple tasks. The use of internal windows also increases safety and the perception of spaciousness for personnel.

5.1.3.1 Functional Adjacencies for the Surgical Suite

The surgical suite must be easily accessible to personnel who will be working in it. The suite should be located so that animals can be moved back and forth between the animal rooms and the surgical suite while minimizing the potential for disease transmission. Sterile supplies and equipment should be readily accessible to the surgical suite.

5.1.4 Necropsy Area

There should be a necropsy area, even in small facilities, unless alternative necropsy services are readily available. A complete laboratory animal care program should monitor causes of death carefully as part of the health surveillance system. In addition, detailed post-mortem examinations of laboratory animals are often required for scientific purposes. In facilities maintaining genetically modified animals, detailed necropsy is a means to discover valuable animal models of disease.

Guideline 14

The necropsy area should be designed to protect personnel and eliminate the potential spread of agents of laboratory animal disease.

The common components of a necropsy area are listed below:

- refrigerated cabinet or chamber, or a freezer
- anteroom
- necropsy room
- fume hood or downdraft table

The purpose and use of the necropsy area must be clearly defined. If the sole purpose is to collect tissues from disease-free animals shortly after death, then a dedicated necropsy area may not be required. Under these conditions, tissues may be collected in the surgical suite or in a biosafety cabinet if the animals are small. However, if the necropsy area is to be used to collect tissue from animals of unknown health status

or to diagnose the cause of death from unknown causes, especially in larger animals, then a necropsy area should be incorporated into the animal facility.

The necropsy area has the potential to expose personnel to agents of disease, and therefore, the suite should incorporate an anteroom. Anterooms offer an effective additional barrier to the facility as a whole by facilitating the staged use of protective clothing and by acting as an air lock, which helps maintain negative air pressure in the necropsy area relative to the adjacent areas.

Equipment that should be considered when designing an effective and safe necropsy area includes surgery lamps, downdraft tables, washing facilities, emergency eyewash, emergency shower, fume hood for perfusions, biological safety cabinet for necropsy of Level 2 biohazard animals, and an anesthesia machine.

The refrigerated chamber for the storage of dead animals can be configured as a pass-through unit. This allows personnel to place animals into the cooler from a general-purpose corridor without the need to take elaborate precautions for biosecurity. The pass-through cooler acts like an air lock in this arrangement, and personnel within the necropsy area can access the dead animals and appended documentation without leaving the suite. This design concept is not restricted to facilities with larger workloads, since appropriate pass-through units as small as domestic refrigerators are commercially available. Freezer units are also useful, especially when carcasses cannot be disposed of shortly after they are necropsied.

Ventilation must be effective to minimize aerosol concentrations and odours. The necropsy area must be at a negative air pressure relative to all surrounding areas. The air exhaust system should be configured to move contaminated air away from personnel performing necropsies and safely expel it from the building. This can be achieved using downdraft tables or exhaust vents at the back of the work surfaces. Flexible exhaust snorkels can also be used. Small animals, such as laboratory rodents, can be necropsied in a biosafety cabinet.

Lighting is very important in the necropsy area. In addition to intensive, adjustable spotlighting or floodlighting, ambient light levels should also be high.

The design of the necropsy area should facilitate thorough cleaning and disinfection, including fumigation if required. The necropsy area, if used for large animals, is subject to frequent wash downs, and large quantities of water are used on a routine basis. There must be floor drains with baskets to capture materials that should be collected for disposal and not permitted to enter the sewer system. Because it is a wet area, all electrical outlets must have ground fault circuit interrupters and waterproof covers.

5.1.4.1 Functional Adjacencies for the Necropsy Area

The necropsy area should be adjacent to procedure rooms or to a dedicated area used for euthanasia and located near the area for waste storage and disposal (e.g., incineration or hydrolysis).

5.1.5 Rooms for the Use of Hazardous Substances

Guideline 15

All rooms where hazardous substances are to be used must meet applicable federal and provincial or territorial regulations and be approved for such use by the local or institutional safety officer.

This guidelines document does not cover the specifications of rooms suitable to house biohazards, chemical hazards, and equipment emitting radiation. The institutional safety officer or a qualified safety consultant must be involved in the planning, design, construction, and commissioning of any component of a proposed animal facility in which any such material or equipment is to be used.

Any area where hazardous materials will be used must be separated from other animal housing and work areas, be clearly identified as a hazard area, and have access restricted to necessary personnel only.

The requirement for shielding depends on the potential of the equipment to create radiation hazards beyond the immediate confines of the room. This must be determined by a clear definition of the specifications of the equipment to be located in the room and compliance with regulations and codes. Examples of equipment requiring shielding that may be used in an animal facility include x-ray apparatus for diagnostic imaging and animal irradiation apparatus involving a radioactive source.

5.2 ENTRANCES FOR ANIMALS AND MATERIALS

5.2.1 Loading Docks

Guideline 16

All loading docks must be designed to prevent access by unauthorized people, restrict the entry of vermin into the animal facility, and prevent cross-contamination among materials and animals being received into or moved out of the facility.

Since loading docks have direct access to the outside, there should be security features in addition to measures to restrict the entry of vermin. There should be two access control points in case intruders are able to go through the exterior access point.

Cross-contamination can be prevented through the use of two separate docks, with SOPs detailing which animals and materials can pass through. Where this is not feasible, and only one dock is available, there should be SOPs for decontamination of the area between activities, as appropriate.

Loading docks should be enclosed and heated.

5.2.1.1 Functional Adjacencies for Loading Docks

Loading docks must open to the outside of the facility. Access from the docks into the facility should enable the movement of animals, feed, and bedding to appropriate areas in a manner that minimizes cross-contamination. Access to the docks from within the facility should enable the removal of waste in a secure manner.

5.2.2 Animal Reception Areas

Guideline 17

There should be a separate ventilated area where animals can be temporarily held under appropriate environmental conditions and be uncrated and examined, if required, before being introduced to an animal room.

There should be two animal reception areas: one for animals with known history who pose a low biosecurity risk and one for animals with higher biosecurity risks. Where separate reception areas are not possible, SOPs to address biosecurity risks must be in place.

5.2.2.1 Functional Adjacencies for Animal Reception Areas

Animal reception areas should be connected to the loading docks in a manner that prevents cross-contamination among animals and materials. This is most easily accomplished by having two loading docks (see Section 5.2.1, "Loading Docks") and two animal reception areas. However, where this is not feasible, there must be SOPs for separation of activities and decontamination of the dock and reception area between activities, as appropriate.

Depending upon management preference, animals that are deemed disease-free may be unpacked and caged in the receiving room using a positively ventilated HEPA-filtered air cabinet, or the transport boxes may be sprayed with disinfectant and taken to animal rooms for unpacking.

Certain animals, such as random-source dogs and cats or captive wild species, must be transported immediately to the designated holding or quarantine and conditioning suite (an inclusion barrier).

5.3 EQUIPMENT CLEANING AND WASTE DISPOSAL AREAS

5.3.1 Cage and Equipment Washing and Sterilization

There should be three separate sections of the cage wash area: dirty, clean, and sterile.

Guideline 18

Facilities should have mechanical cage washers.

Facilities must have sanitation equipment and should have sterilization equipment that accommodate the needs of the facility.

Sanitation and decontamination of cages, racks, water bottles, and other washable and heat-resistant items, such as carts and mobile stainless-steel equipment, are best achieved using mechanical washing machines and autoclaves designed and programmed for this purpose. In addition to the consistency of effective operation and monitoring of these units, cage washers provide a safe and effective means of applying detergents, disinfectants, and descalers appropriate to the need. Cage washers should operate according to the

manufacturer's recommendations and supply water at the temperature and contact time required to achieve appropriate sanitization. There should be regular verification that the cage washer is sanitizing effectively. Pass-through cage washers should be used. This allows the cleaned equipment to be removed from the machine on the clean side of the cage or equipment washing area following completion of the cleaning cycle.

Mechanical washers or designated areas should be available for pressurized washing of large equipment such as racks and large cages.

Guideline 19

The cage wash area must have adequate ventilation, temperature, and humidity controls, to maintain a safe environment conducive to human physical activity and to prevent the spread of vapour and contaminants.

The aerosols generated in the sanitation of dirty cages and equipment (e.g., water bottles) should be effectively contained. Vented hoods and filtered bedding disposal units should be used and therefore should be accommodated in the dirty area. Vacuum systems for soiled bedding removal are also available.

Dirty cages awaiting attention give off foul odours and gaseous ammonia, which is especially heightened at the time of soiled bedding removal. Where animals were exposed to biological or chemical hazards, the bedding from cages is particularly harmful to personnel. Therefore, ventilation, engineering controls (e.g., pressure differentials), and SOPs in the cage wash area, particularly on the dirty side, should be in place.

Ideally, clean and dirty activities in the cage wash area should be segregated physically. The clean side of the cage washer generally does not have to be as large as the dirty side since there is less activity in this area, and the clean cages and equipment should be moved to clean cage storage or back to the animal rooms for immediate use. It is common practice to refill cages with clean bedding in the clean area, and hence, there should be room for holding bedding and a bedding dispenser where required (note: ventilated automatic bedding dispensers reduce the exposure of personnel to airborne dust).

In very small facilities where separate soiled and clean cage wash spaces cannot be accommodated, there must be a process-driven function, with SOPs that are validated through testing, for contamination. Cages should be cleaned in small batches and the area surrounding the cage washer must be thoroughly sanitized before the clean cages are removed from the cage washer.

Guideline 20

The dirty cage storage areas should be large enough to accommodate all dirty cages awaiting processing, unless there are alternative designated dirty staging areas with appropriate ventilation.

Diagram 7 illustrates the key components needed in a cage wash area. The dirty side of the cage wash area should be large enough to accommodate the accumulation of dirty equipment throughout the working day (i.e., a staging area). The size is based on the rate at which dirty equipment can be processed through the cage washer and the daily generation of dirty equipment. Overflow of unprotected dirty equipment in general access corridors or animal rooms is unacceptable. In large facilities or where the dirty cage wash area is

limited, it may be necessary to design separate dirty staging areas with independent ventilation. The clean side of the cage washer should have a staging area for clean equipment.

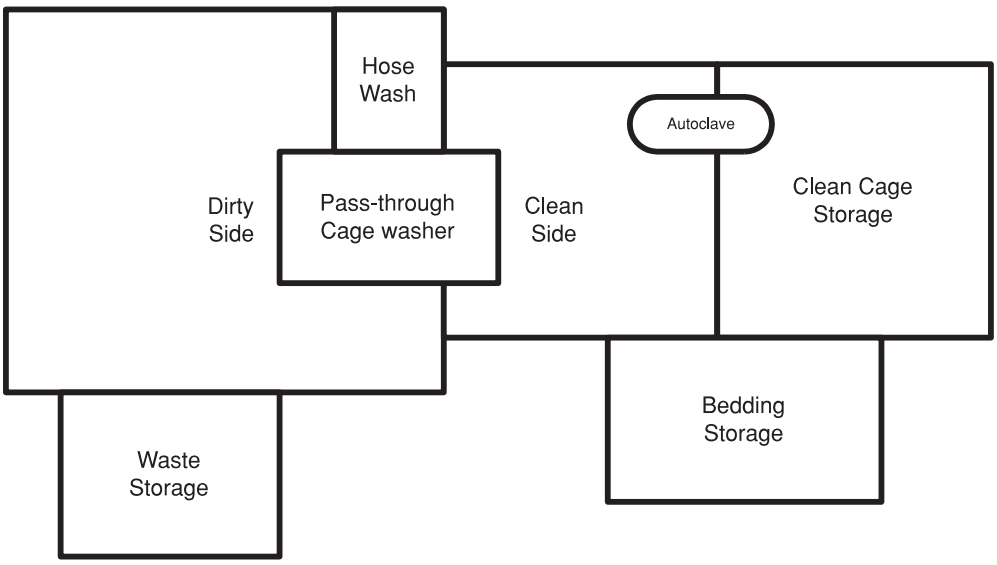


Diagram 7 Key components of a cage wash area

Space is also required for the manual or automated removal of soiled bedding. Sinks for handwashing and large deep sinks for prewashing and washing specialized equipment are extremely useful in this area. If hose-down prewashing of cages or racks is required (e.g., for large primate and dog cages), a walled-off bay with hot and cold water and a disinfectant dispenser should be incorporated. Such bays need efficient exhaust air venting.

Robotic equipment can be used for dumping and preparing cages for cleaning. It reduces the workload; minimizes personnel exposure to allergens, potential biohazards, noise, and heat; and can limit repetitive motion injuries (see Section 10.2, "Safety of Personnel"). In most cases, the size of the dirty side of the cage wash area needs to be increased significantly to accommodate a robotic unit.

Guideline 21

The differential pressure on the dirty side of the cage wash area must be strongly negative to all surrounding areas, with the exception of necropsy and containment areas.

Washing machines generate a great deal of heat, and large amounts of steam are released when the doors are opened, especially on the clean side. Steam must be effectively exhausted for the comfort and safety of personnel, to prevent the spread of contaminants, and to prevent damage to the surfaces in the washing area. There should be stainless-steel exhaust vents adjacent to each washing machine door.

Washing machinery generates considerable noise and vibration. This is compounded by the disassembly and assembly of plastic and metal cages and other equipment in the area. Noise and vibration can be a problem

for personnel working in the area and for animals in rooms nearby, and measures should be taken to attenuate the sound and isolate the washing machinery. The density of the peripheral walls of this area often needs to be greater than the normal sound attenuation specifications in the rest of the facility (sand-filled concrete masonry units, poured concrete, etc.). The use of cavity walls may also provide sound attenuation. Doors, both between the dirty side of the washing area and the corridor, and between the clean side of the washing area and the corridor, should be designed for sound attenuation and prevention of the spread of contaminants.

The incorporation of an autoclave into the cage wash area is dependent on the type and needs of the facility and the SOPs that will be put in place. For a single- or limited-purpose facility, such as a genetically modified animal barrier facility, it may make sense to incorporate an autoclave into the cage wash area for sterilization purposes. However, for larger multipurpose facilities, a pass-through autoclave is best incorporated through the perimeter wall of a specific zone that will require its use, such as between the clean cage storage and a viral-antibody-free mouse unit.

Biosafety guidelines may require autoclave sterilization of cages before cage washing. Depending on the facility, cage setup, and specified pathogen, the cages may have to be autoclaved prior to dumping the bedding. In most cases, it is preferable to locate the autoclave at the containment barrier.

5.3.1.1 Sterilization

It is often necessary to sterilize cages, water bottles, bedding, feed, and other equipment to be used in an animal facility or within specific zones. This is usually accomplished by physical or chemical means, such as autoclaving and fumigation.

Guideline 22

Appropriate sterilization equipment should be installed in strategic locations where it will be the most effective, such as within the area where it will be used or at the transition between zones of the animal facility.

Physical Sterilization

Steam sterilization under pressure (i.e., autoclaving) is the principal means of sterilization for cages, water bottles, bedding, and equipment in controlled scientific environments. In facilities where there is a requirement to provide sterilized equipment and food centrally, an autoclave can be located in the clean area of the cage wash or between the dirty and clean sides of the washing area. In some cases, a pass-through autoclave can be placed between the clean side of the cage wash and the clean equipment storage or staging area. Thus, bedding can be automatically dispensed in the clean side of the cage wash, and then cages containing bedding can be autoclaved through to the clean cage storage area.

Dry heat sterilization is particularly suited to materials that will be damaged by moisture and substances that are hydrophobic. Manufacturers should be consulted in determining whether steam or dry heat sterilization is appropriate.

Ionizing radiation is not commonly used for sterilization purposes in animal facilities. It is used for the commercial sterilization of rodent feed manufactured for use in exclusion barrier units and wherever biosecurity

is an issue. Its use has significantly reduced the amount of feed sterilized by autoclaving since the sterile food is now readily available commercially.

Ultraviolet light can be used to sterilize surfaces; however, shaded areas are not sterilized. It can also be used to assist in reducing the microbial count in water treatment systems. The hazards of ultraviolet light sterilization include accidental exposure and possible ozone production in excess of allowable amounts. The costs of quality assurance, maintenance, and hazardous waste disposal are all serious issues. Its application should be reviewed carefully with this in mind.

Chemical Sterilization

Sterilization can be achieved by exposing items of equipment and entire rooms to gaseous microbiocidal chemicals. If this form of sterilization is to be used, the materials selected for construction of the animal facility should be compatible with the proposed chemical sterilants and the sterilization equipment or area in which it will be used should be maintained under negative pressure and effectively exhausted, as the vapours from chemical sterilization are toxic.

Pass-through chambers using microbiocidal chemical gases and vapours at exclusion and inclusion barrier interfaces are desirable for the sterilization or decontamination of larger items of equipment, particularly those that cannot be moist- or dry-heat sterilized.

Hydrogen peroxide vapour is an effective and safe chemical sterilant in animal facilities. The vapour-generation apparatus is portable and, together with specific delivery systems, has a wide range of applications. Hydrogen peroxide vapour is toxic to animals; however, the residue from this sterilization process is oxygen and water only. There are rack cage washers that can be used as the sterilization chamber in conjunction with the hydrogen peroxide sterilant units.

Chlorine dioxide gas can also be used to sterilize rooms and equipment within enclosed spaces. Formaldehyde gas and paraformaldehyde are highly effective for decontamination, particularly in areas at high risk of contamination; however, the gas is toxic, a serious irritant, and time-consuming and tedious to use and vent effectively. Systems that employ a combination of hydrogen peroxide and ozone are being used to sterilize reusable medical devices.

Peracetic acid can be used as a secondary method of sterilization for items being loaded into flexible film isolators. However, it is toxic, and personnel must wear respirators during this process.

5.3.1.2 Functional Adjacencies for Cage and Equipment Washing and Sterilization

There should be a clean access route with associated procedures that links the clean side of the cage washer with the animal rooms and storage areas for clean bedding, cages, and equipment. Similarly, there should be an access route and procedures linking the dirty side of the cage washer to the animal rooms and waste storage and disposal. Many cage wash areas also have a sterile section.

5.4 STORAGE AREAS

5.4.1 Feed and Bedding Storage

Guideline 23

Animal feed and bedding should be stored off the floor and away from the walls in a dedicated, temperature-controlled room that is free of vermin.

The feed and bedding storage room should be easy to sanitize to prevent contamination. Feed and bedding should be stored on plastic or metal pallets or shelves that are located away from the walls to facilitate cleaning and monitoring of vermin. Sealed containers must be available to hold all open bags of feed.

For laboratory feed, room temperature and a relative humidity of 50% is suitable, provided the feed is used in less than six months. Clean bedding may be stored in the same room as animal feed.

Products and equipment that could potentially cause contamination or deterioration of feed or bedding should not be stored in the same room as the feed and bedding. If they need to be kept in the same room, they must be stored in a secure cabinet that will prevent contamination of the feed and bedding.

5.4.1.1 Functional Adjacencies for Feed and Bedding Storage

The feed storage area should be accessible from the receiving area and from the animal rooms. The bedding storage area should be accessible from the receiving area and the clean side of the cage wash area unless the bedding is to be transferred to the cage wash area via a vacuum system. For larger species, bedding storage should be adjacent to the animal room.

5.4.2 Clean Cage and Equipment Storage

Guideline 24

Adequate storage should be available for all cages and equipment not in active use.

An adjacent short-term holding area for clean cage storage or staging should be located in such a manner that clean cages and equipment can be moved there directly from the clean side of the cage wash area. Clean cages and equipment should not be stored in corridors or animal rooms.

Adequate clean equipment storage should be available to accommodate all clean equipment in active use. Storage of equipment in active use is sometimes referred to as live storage. Approximately 15-20% of the net utilizable space of the animal facility should be allocated for live storage. The amount of required storage space is usually higher when there are a variety of species or groups of animals of different microbial statuses being held. Careful consideration should be given to the type of cages and equipment to be washed and the potential storage time in order to estimate the actual storage requirements. Where storage space in the facility is limited, equipment designated for long-term storage should be stored in designated storage areas outside the animal facility.

5.4.2.1 Functional Adjacencies for Clean Cage and Equipment Storage

There must be a clean access route from the clean storage area to animal rooms and procedure rooms. The clean cage and equipment storage area should be located near the clean side of the cage washer and the clean bedding storage area.

5.4.3 Janitorial Closets

Guideline 25

Sufficient space must be available in designated areas to store cleaning supplies and cleaning equipment.

Janitorial services from institutional building service units should not be used in animal facilities, for biosecurity and biosafety reasons. Separate cleaning supplies and equipment are required in different zones of the facility, and closets for the storage of janitorial materials and equipment should be located in each distinct zone or activity area. Each animal room should have dedicated cleaning equipment. Cleaning supplies and equipment must be stored away from the animals and must not be stored in corridors.

5.4.4 Waste Disposal and Storage

5.4.4.1 Waste Disposal

Guideline 26

Where safe waste disposal cannot be accomplished through existing local services, appropriate space and equipment must be available to ensure the safe elimination of waste.

Procedures for the disposal of soiled animal bedding and the remains of dead animals depend on local codes, the availability of acceptable waste elimination equipment, and the presence or absence of biohazardous agents and toxic substances in the discarded material.

In certain jurisdictions, it is permissible to send non-toxic and biologically safe, soiled laboratory animal bedding to appropriately designated landfill sites. However, practices that involve access to general public waste disposal systems may pose risks, and consideration should be given to equipment that is capable of reducing the waste materials generated in the animal facility and rendering them harmless.

The requirement for waste elimination equipment to be a part of a new facility or be housed at another location within the institution, or for waste material to be transported to a private or public waste elimination facility, should be clearly identified in the planning process. The decision will influence loading dock design, appropriate functional adjacencies, and access to waste elimination equipment.

There are two principal methods of maximally effective and safe elimination: incineration and alkaline hydrolysis or digestion.

5.4.4.1.1 Incineration

Incineration is an effective method of waste elimination but uses large amounts of energy produced by the combustion of fossil fuels and contributes substantial quantities of carbon dioxide to the atmosphere. Permits are required for new incinerators and should be sought prior to pursuing this method of waste elimination.

The disposal of soiled animal bedding and carcasses by combustion can be accomplished by high-temperature incineration. The waste material is loaded into the primary chamber and a secondary chamber (usually mounted above the primary chamber) receives volatile substances and gases from the initial combustion process and pyrolytically converts them into simple, harmless chemical components.

A temperature of 927°C is effective for tissues that are not chemically contaminated; a temperature of 1010°C to 1099°C is required to eliminate all potentially toxic substances.

5.4.4.1.2 Alkaline Hydrolysis or Digestion

When alkaline digestion is being considered for laboratory animal disposal, the compatibility of the effluent with local codes should be determined. Alkaline digestion converts animal tissues into a sterile, neutrally reactive, aqueous solution that can be disposed of in a sanitary sewer. However, there are some issues related to the disposal of the effluent; for example, its pH is generally 11-12, the effluent can solidify in the waste piping, and biochemical oxygen demand levels can be greater than tolerable levels.

Laboratory-sized tissue digesters with up to 5 kg capacity are suitable for laboratory rodent and rabbit carcasses from Containment Level 3 units. The laboratory-sized units operate at much lower temperatures (approximately 98°C) than larger commercial units, and the complete operating cycle may take up to 18 hours. However, 150°C and 400 kPa for 3-8 hours are required for deactivation of prions, the agents of transmissible spongiform encephalopathies (Creutzfeldt-Jakob disease, variant Creutzfeldt-Jakob disease, bovine spongiform encephalopathy, scrapie, and chronic wasting disease) (Government of Canada, 2016).

5.4.4.2 Waste Storage

Guideline 27

The waste storage area must be large enough to accommodate all waste accumulated between disposals.

The waste storage area must provide adequate storage for animal excrement, soiled bedding, and waste feed and should be designed to facilitate its sanitation. If the waste is not removed on a daily basis, consideration should be given to cooling the waste storage room.

Guideline 28

The ventilation system for the waste storage area must be designed so that exhaust from this area cannot enter any part of the building or adjoining buildings.

There must be a disposal system or appropriate procedures that prevent dirty bedding contamination in the facility. A vacuum disposal system is an ideal option.

Guideline 29

Where biohazardous waste, hazardous materials, or waste containing radionuclides will be produced, appropriately appointed areas must be available for storage and disposal in accordance with federal, provincial or territorial, and municipal requirements.

Federal, provincial or territorial, and municipal governments are all involved in the regulation and oversight of hazardous waste disposal. The Canadian Council of Ministers of the Environment, composed of the environment ministers from federal, provincial, and territorial governments, has determined waste management to be a priority and has developed guidelines in this area. Additionally, the Canadian Nuclear Safety Commission oversees the disposal of radioactive waste, and the transportation of hazardous wastes is regulated by the *Transportation of Dangerous Goods Regulations* (Government of Canada, 2023).

5.4.4.3 Functional Adjacencies for Waste Storage

The waste storage area should be easily accessible from the dirty side of the cage wash area. Preferably, waste storage should be located outside of the main core of the animal facility. It should also be closely linked with the loading dock. This may differ if transfer occurs via a vacuum conveyor.

5.5 PERSONNEL AREAS

5.5.1 Office and Reception Area

Guideline 30

For biosecurity and safety reasons, access to the laboratory animal facility must be controlled.

All access points should be designed with two control points that people entering the facility must pass through.

The facility should be designed such that all personnel enter or leave the facility through the reception area. This can facilitate visual observation of individuals. The reception area also provides a point for personnel communication and the pick-up and drop-off of inocula and samples. Where this is not practical, other forms of monitoring should be used at remote entries, such as restricted card access or cameras interfaced with intercoms.

Offices are required for administrative, senior technical, and veterinary personnel, and may include space for continuing education materials and a training centre. A centralized office suite facilitates ongoing communication between the various groups responsible for the effective operation of the animal facility. This area should have dedicated space for maintaining physical copies of important facility documents, such as SOPs and safety data sheets (SDS). The centralized office suite may be located outside the facility or at the

interface to the animal facility entrance. However, this will not remove the need for desk space or computer space within the facility or specific zones of the facility, as space for filing and consulting animal protocols, SOPs, relevant institutional policies, and animal records must be provided within the facility.

Exterior windows should be provided in spaces used solely for human occupancy, keeping in mind security requirements.

5.5.2 Changing Rooms

Guideline 31

Personnel areas should be designed and strategically located to facilitate mandatory hygienic practices and biosecurity measures that minimize the risk of releasing or introducing zoonotic agents.

Personal hygiene is extremely important to the proper maintenance of a laboratory animal care program. Changing into facility clothing and footwear, and, where deemed necessary, the use of showers and air showers by animal care, research, teaching, and testing personnel accessing the facilities reduces the risk of the mechanical introduction of etiologic agents of diseases. Additionally, showering and changing at the end of the day reduces the risk of a zoonotic agent being released from the facility.

Attention to the spatial design and furnishings in changing facilities is important, to encourage practices that minimize the risk of cross-contamination. Important considerations include well-secured lockers of an appropriate size, seating for changing footwear, showers that are warm and comfortable with shelf space for personal cleaning products, the option of privacy for changing, and mirrors and shelves for grooming, particularly prior to leaving for the day. Adequate space to put out clean facility clothing and towels should also be included in the design criteria.

5.5.3 Toilets

Guideline 32

Each toilet should be enclosed in a separate room with the relative air pressure negative to surrounding areas, or positioned under the exhaust grilles within the general entry locker area.

Toilets should be strategically positioned in the different zones of the animal facility, especially where a change of clothes is required when moving from one zone to another. However, in some cases, it may not be acceptable to have a toilet in a biocontainment area (Government of Canada (2022)). Each toilet should be housed in an enclosed room with continuous air exhaust (i.e., they should not be in stalls that are separated from a larger room by partitions). The room should be under strong negative pressure, and the make-up air should be drawn from an adjacent change room or corridor. Toilets that are designed to minimize the generation of aerosols should be used.

5.5.4 Break and Meeting Rooms

A break room should be provided with adequate space for comfortable seating at tables. In addition, a place for a refrigerator, dishwasher, microwave, and sink, an area for preparing beverages, and access to chilled water should be considered.

Windows to the outside environment are desirable if the location makes this feasible. Natural light can also be directed into enclosed spaces via natural light tubes.

This room may also be useful for meetings and as an information centre for personnel (which can include items such as books, journals, newsletters, catalogues, notices, and Wi-Fi access).

5.5.5 Laundry

The use of an in-house laundry facilitates the frequent laundering required, particularly where commercial laundries do not provide a cost-effective option. Most facilities supply clothing for work within the facility and may require frequent changes between zones within a facility.

5.5.6 Functional Adjacencies for Personnel Areas

Facilities used by personnel (e.g., reception, change and shower facilities, washrooms, and breakrooms) should be located to accommodate the needs of personnel working in the facility, while adhering to requirements for biosecurity and biosafety. The reception area should be located near the main personnel entrance to the facility. Locating the office area for administrative, senior technical, and veterinary personnel adjacent to the reception area and main entrance to the facility can facilitate the receipt of materials. However, it may be preferable to locate the offices in an alternate area if the entrance to the animal facility does not provide the best environment for personnel (e.g., lack of access to daylight).

Change and shower facilities should be located near the personnel entrance to the facility and, if required, at the transition area between zones within the facility. Anyone entering or exiting the facility beyond the reception area should pass through the change and personal hygiene facilities to ensure established SOPs for biosecurity and biosafety can be consistently maintained and monitored. Where inclusion or exclusion barriers are maintained as a specific zone within the animal facility, appropriate changing and showering facilities may also be required at the periphery of these zones. They are often incorporated into the barrier, such that personnel are forced to go through the change room or shower to enter the next area.

Toilets should be placed within barrier units so that personnel do not have to go through a complete change of clothes to visit the washroom. For biocontainment areas, current biocontainment standards must be consulted to determine the acceptability of washrooms within these areas.

The break room should be located at the perimeter of the animal facility and close to the personnel entrance and changing or shower areas. The break room may be accessed from either outside or inside the perimeter, but not both. It may also be effective to have the break room located near the administrative offices. In some cases, it may be necessary to have separate break rooms for different zones within the facility. However, in the majority of animal facilities, the break room can be positioned so that it is available to most personnel using appropriate access protocols. Precautions should be taken to prevent food odours from entering other areas of the facility.

5.6 CORRIDORS

Corridors are an extremely important component of an animal facility. They must be strategically located to interconnect the various components of the animal facility and enhance efficient traffic flow.

Guideline 33

Corridors must meet fire, safety, and building code regulations and be wide enough and have sufficient protection to permit regular movement of large items (e.g., cage racks) and the replacement of large equipment (e.g., boilers and cage washers) in a safe manner without causing damage to the facility or the equipment.

Corridors or hallways should be configured to facilitate the movement of personnel and equipment. Corridors should be a minimum of 2 metres wide (and preferably 2.2 metres in order to give 2 full metres of clearance after bumper rails have been added). Where bottlenecks for equipment may occur, corridors should be wider to prevent obstruction to traffic during busy times.

The walls should be protected with a bumper rail that is impact resistant and facilitates thorough cleaning and disinfection. Bumper rails should curve around corners (bull-nosed corners facilitate this feature). Curbs may also be used to prevent equipment from damaging wall surfaces.

Corridors should be designed so they can be cleaned and disinfected at relatively frequent intervals, based on the frequency and sources of traffic.

Guideline 34

The layout of corridors and other components of the facility should enable efficient movement of people, animals, equipment, food, bedding, and waste in a manner that minimizes biosecurity and biosafety risks.

Once the components of the animal facility and their functional adjacencies are identified, the manner in which people, animals, materials, and equipment will move around the facility should be considered. The risk of cross-contamination can be reduced through the application of containment and engineering controls. Where facilities have a one-corridor system, SOPs must be in place to ensure there is no cross-contamination that could affect people or animals.

5.7 BARRIERS

Guideline 35

Barriers for bioexclusion and biocontainment should be strategically designed and located throughout the laboratory animal facility to minimize the potential for cross-contamination and to segregate incompatible activities.

Barriers in the context of animal facility design consist of a combination of physical systems and performance criteria that together minimize the transfer of etiologic agents of animal or human disease from one side of the barrier to the other. Diagram 8 illustrates some potential means for the transfer of etiologic agents across barriers. The barriers should be designed to reduce the potential of transfer by these means to the extent dictated by the risk and the scientific requirements.

Barriers form an integral part of all animal facilities, and therefore, the basic concepts are described here. However, this discussion is not an alternative to biosafety standards describing the facilities and procedures to be used when working with human or animal pathogens. Current biosafety standards must be consulted in all cases where animals are infected with known human or animal pathogens (see Government of Canada, 2022).

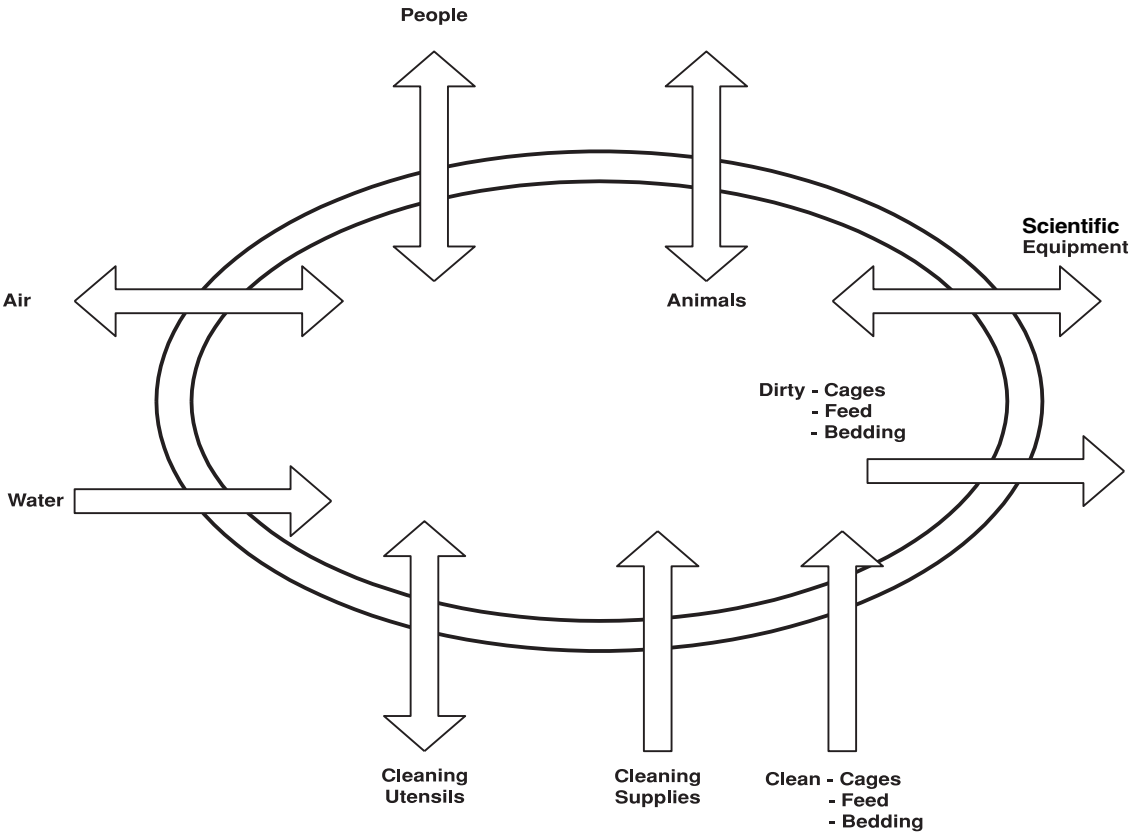


Diagram 8 Barrier challenges

Barriers are divided into two categories: inclusion and exclusion barriers.

Inclusion barriers prevent the escape of agents of disease from the animals in the unit to the outside (biosafety). Inclusion barriers may be established to quarantine or isolate animals of unknown health status or to contain animals intentionally infected with human or animal pathogens (biocontainment). They may also be used to manage an animal or group of animals in which there is an outbreak or potential for an outbreak of infectious disease that is not a threat to people or biosafety. This comes under the activity of animal isolation or quarantine and is relevant to the biosecurity of animals of the same species and others known to be susceptible to the disease. Areas within these barriers should have HEPA-filtered exhaust.

Exclusion barriers prevent the entry of animal infections and infestations from outside sources (biosecurity). Exclusion barriers are often established to protect the health status of laboratory animals such as virus-antibody-free rodents, immunocompromised animals, and particular genetically modified animals.

It is important to note that an exclusion barrier does not prevent infectious material from escaping into the environment, and an inclusion barrier will not prevent an infectious disease from outside crossing inside the barrier. As a result, it is sometimes necessary to combine physical and operational features of exclusion and inclusion barriers. For example, housing immunocompromised animals challenged with a pathogenic organism would require the use of an inclusion and exclusion barrier.

A barrier can be created at the cage, rack, room, suite, or facility level and combinations of these are used frequently. The following components can be used to create barriers in an animal facility:

- Doors with appropriate weather stripping and spring-loaded door sweeps, effectively deployed when the doors are shut, form simple barriers. By introducing SOPs for changing footwear and donning protective clothing on entering the room and removing it on leaving, a stronger barrier may be created. Interlocking doors at interfaces to various zones permit only one door to be open at a time, thus improving the air barrier between zones of different status.
- Hand-free sinks, positioned close to the door of an animal room, should be used on entering and exiting the animal room. The efficacy of handwashing as a simple barrier procedure has been well established.
- Air locks may be used as barriers and consist of tightly fitting doors on a pass-through chamber for passing clean or chemically sanitized equipment into the barrier facility only.
- Anterooms or vestibules to rooms greatly improve the potential to create a simple and effective barrier. The differential air pressures (positive or negative) in the animal room can be maintained more effectively with an anteroom. The anteroom acts as a simple air lock, preventing the retrograde movement of room air to the corridor or vice-versa, depending on the set differential pressures. The anteroom also provides a halfway stage in and out where extra layers of protective clothing and footwear can be donned or removed. The anteroom should contain a handwashing sink to further assist in establishing an effective barrier.
- Change rooms are components of barrier suites or entire facilities. The change room area is divided into two spaces, one on the outside of the barrier and one on the inside, usually separated by a shower unit. Clothes are removed in the outside change room, and clean (sterilized) clothing and protective clothing (over-garments, hats, face masks, gloves, etc.) are available in the inside room. In a complete exclusion barrier unit, the objective is to prevent anything dangerous from entering the area, and therefore, showering-in may be required. Air showers are sometimes used as an alternative to water but are much less effective. In the full inclusion scenario, all clothing must be removed before leaving, and individuals must shower-out using appropriate soaps and disinfectants.
- Pass-through autoclaves can be installed at the room, suite, or facility level as an important tool in establishing an effective inclusion or exclusion barrier. They may be used to sterilize material either into or out of the unit.
- Fumigation or disinfection chambers, usually small pass-through rooms, can be positioned at the barrier and are used to chemically sterilize larger items of equipment safely. The chamber operates at slightly negative pressure during the exposure process. A manually activated exhaust fan is used to evacuate the chamber.

- Disinfectant transfer tanks (dunk tanks) may be used for the transfer of waterproof objects across barriers by immersion in a disinfectant solution. Dunk tanks contain self-sterilizing liquid but should not be used as the sole means of decontamination.
- Constant air pressure differentials can be maintained through the control of supply and exhaust air.
- HEPA filters can be used as effective barriers against the transfer of airborne disease organisms.

Some or all of the above components can be used to establish the physical features of a barrier unit. The final integrity of the unit depends on the protocols for entry and exit of personnel and material, and the differential air pressure determines whether it is an inclusion or exclusion barrier. Diagram 9 illustrates the use of many of the above components to establish a barrier suite.

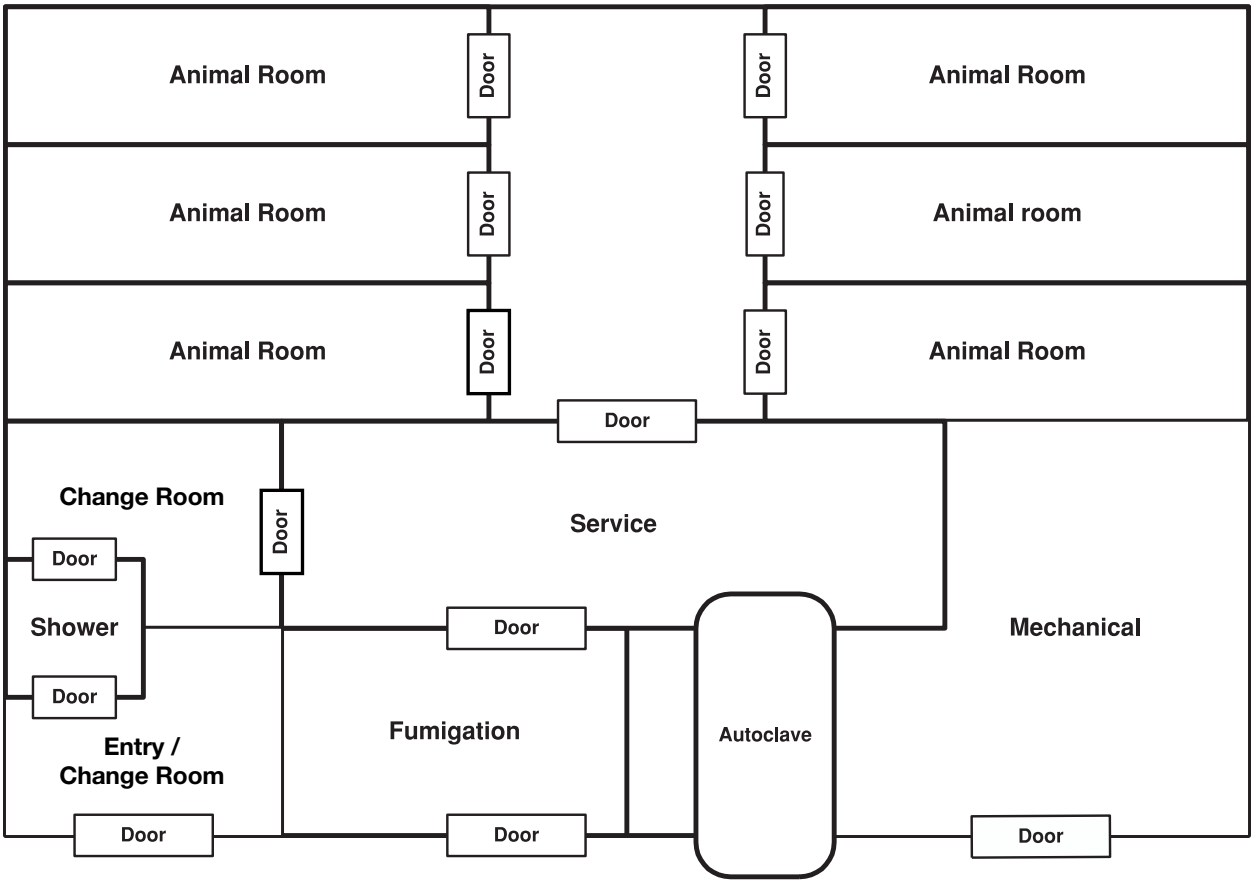


Diagram 9 Barrier system

The relative number of animals maintained within any barrier unit may vary considerably. Therefore, it is extremely useful to incorporate flexible barriers into an animal facility, such that the relative size of the barrier can be changed according to demand. In Diagram 10, which illustrates a flexible barrier in a U-shaped corridor, the relative size of the barrier suite can be varied from A to C by sealing off the appropriate set of corridor doors. In Diagram 11, which illustrates a flexible barrier in a facility with a double corridor, the relative size of the barrier can be increased or decreased by altering the opening of the room to either the barrier corridor or the conventional corridor, respectively. The ventilation system in flexible barrier systems

must be designed (segmented) to accommodate the potential size of the barriers. Where flexible barriers are constructed, there must be effective separation between the active and non-active barrier areas.

It is also possible to create temporary or portable barriers within existing or new structures with the use of soft-wall structures that are supplied with HEPA-filtered supply or exhaust systems. These types of units, when run under positive pressure, are useful as portable surgical units for laboratories, as a means of providing an ultra-clean room within conventional facilities for housing immunocompromised animals, and for the maintenance of some animals with a particular genetic modification. They are also effective in reducing potential allergens. Facilities must have the capacity to maintain appropriate conditions within these units for the activities that will be undertaken. These soft-wall structures should not be used as an alternative to maintaining the facility in good repair. If plastic vinyl slatted doors for entry and exit are used, a strict sanitization program must be put into place, as the doors can act as fomites and transfer organisms to other equipment and carts.

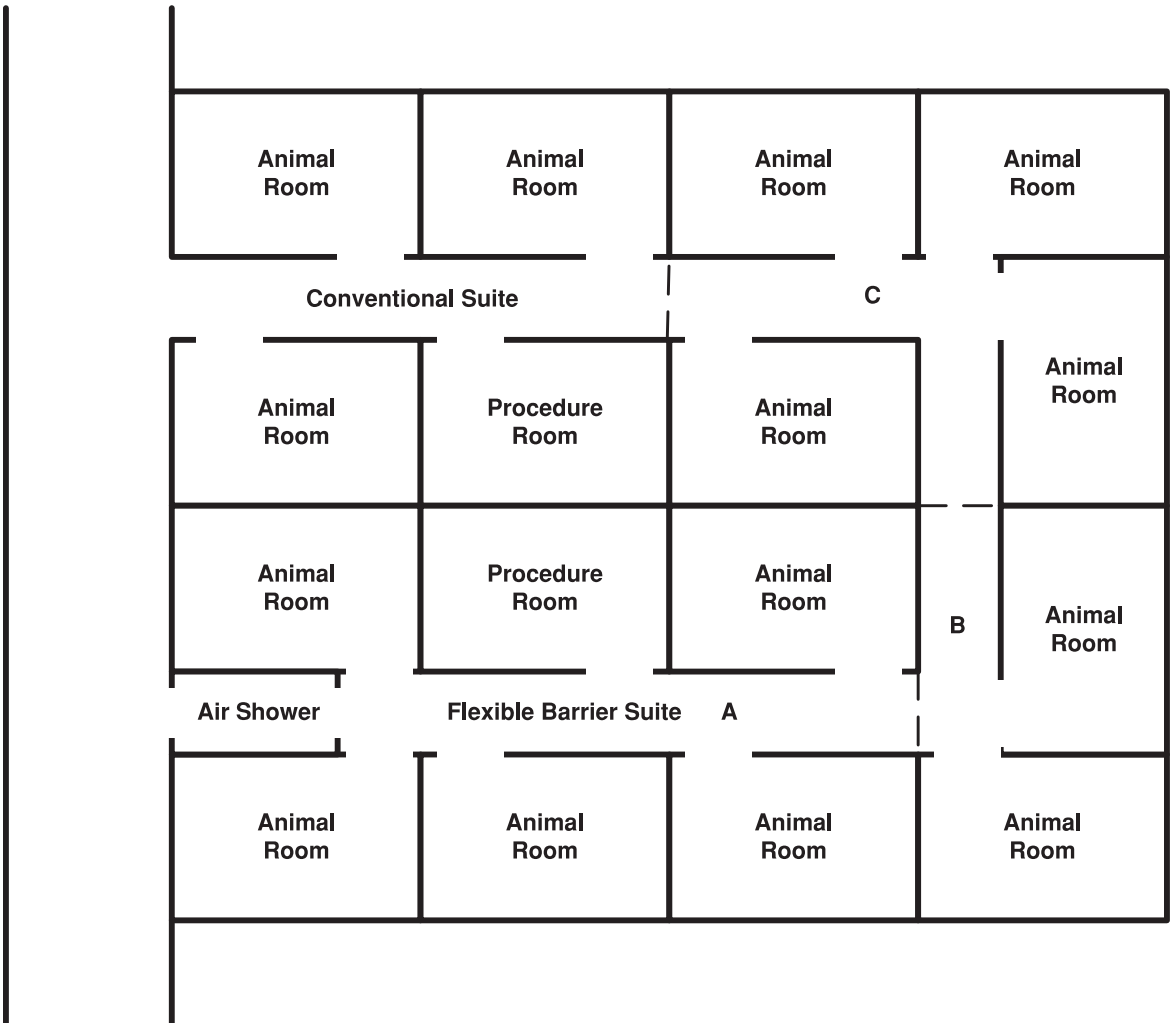


Diagram 10 Flexible barriers – U shaped corridor

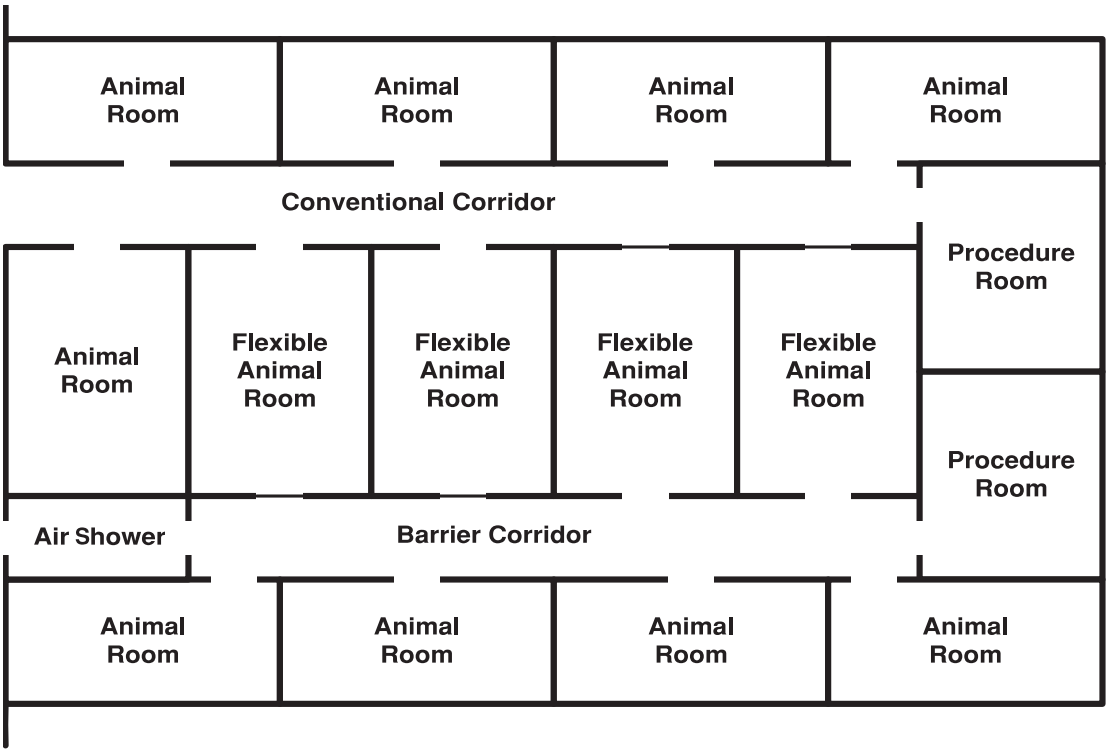


Diagram 11 Flexible barriers – double corridor

Mobile and lightweight air filter power units pass air through HEPA filters. Unfiltered incoming air to a room can be directed to such a power unit using flexible ducting. Depending on the size of the power unit, 100 air changes per hour or more are commonly achieved. Use of this technology with an attached or enclosed biosafety cabinet or animal change station; autoclaved cages, food, bedding, and other accessories; combined with carefully developed procedures, can provide a high level of cleanliness for animal housing within such a room unit.

5.8 MECHANICAL AND ELECTRICAL SPACE AND DISTRIBUTION OF SERVICES

The mechanical services for an animal facility are extensive and complex because of the need for strict control of environmental parameters and the importance of adequate redundancy at multiple levels to cover outages and potential disaster scenarios. The mechanical space required for an animal facility is comparatively large relative to the overall facility, if compared to a building designed solely for human occupancy.

Guideline 36

Adequate space must be available to accommodate the mechanical, electrical, and plumbing services and to allow servicing of this equipment with little to no disturbance to the animals.

Mechanical and electrical equipment should be located so that they are accessible from outside animal rooms and other critical areas such as surgical suites, necropsy areas, and restricted zones (e.g., containment and exclusion areas, such as Containment Level 2 or 3, nonhuman primate housing, and clean barriers).

Central electrical panels and electronic monitoring and communication equipment require dedicated spaces.

The distribution of supply and exhaust air duct work is complex and spatially demanding. In addition, temperature control in the individual animal holding spaces is most frequently achieved by reheat coils on the supply air side.

Plumbing distribution is extensive and may include piped gases from a central supply and main line sources.

Institutional physical plant maintenance personnel should always be represented on the user group team during planning, design, and commissioning to ensure that their required activities are represented and can occur unimpeded with minimum interference to the scientific and animal care personnel (see Section 2, "Planning and Design", and Section 4.2, "Commissioning").

Possible locations for the mechanical services are illustrated in Diagram 12. Mechanical services should be located so that maintenance of the equipment can be achieved without having to enter the animal facility, such as in an interstitial or epistitial space. Where this is not feasible, the facility should be designed so that mechanical services can be maintained from the main corridors without the requirement to enter animal rooms, procedure rooms, and restricted zones.

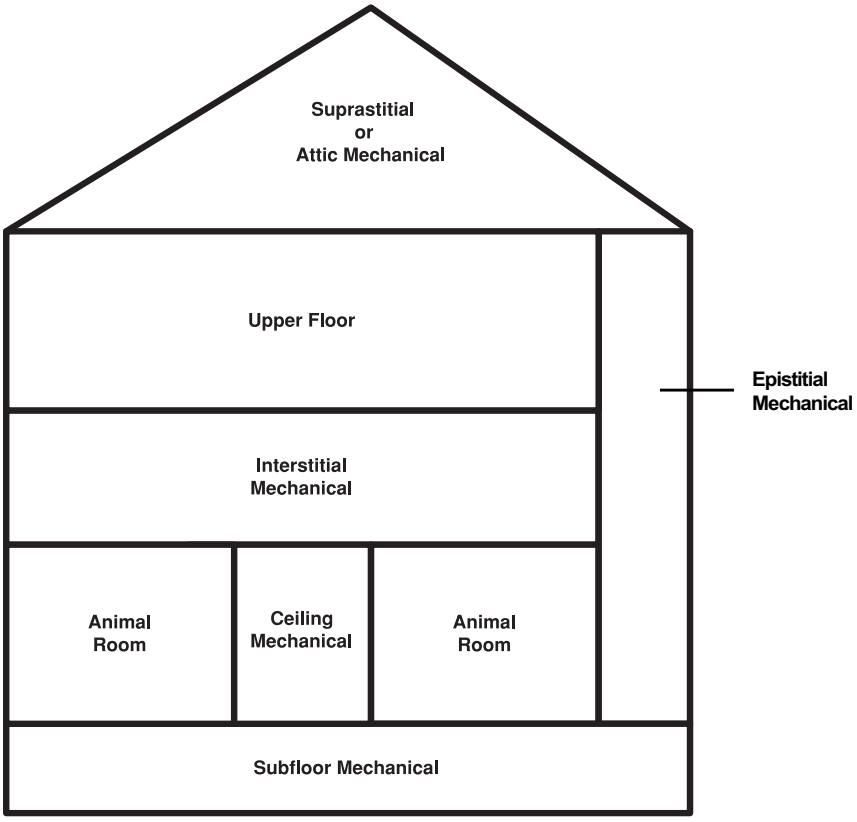


Diagram 12 Possible locations for mechanical services

5.8.1 Functional Adjacencies for Mechanical Services

Mechanical and electrical equipment and the distribution system should be located to enable servicing and repair from outside the facility, especially for barrier areas or suites. This can be accomplished by placing mechanical services on a separate floor adjacent to the animal facility or in the interstitial or epistitial spaces of service corridors. Interstitial space, or attic or suprastitial space in single-story buildings, has the advantage of providing separate access for service and repair personnel, with easy access to equipment for servicing (reheat boxes, dampers, air filtration system, etc., and all the distribution lines, conduit, and piping) and access to lighting from above, without disturbing the integrity of the rooms below.

Where floor-to-ceiling height is substantial, distribution systems can be located within the ceiling spaces of corridors; however, service and repair personnel will need to enter the facility. Where space restrictions require the mechanical distribution systems to be located above the ceiling of an animal room or procedure room, access for servicing should be from the corridor or anteroom and not from within the room. Diagram 12 illustrates potential locations for mechanical services.

Some mechanical components, such as pumps and fans, are noisy and are often associated with a significant amount of vibration. This type of equipment should be located outside the facility when possible, with sound and vibration attenuation.

The cage wash area should be designed so that the cage washer and the autoclave, if present, can be serviced from the dirty side. In biocontainment facilities, the body of the autoclave should be on the clean (uncontaminated) side of the barrier.

6 MATERIALS AND FINISHES

Guideline 37

Laboratory animal facilities must be designed to facilitate sanitation processes. Materials and finishes must be durable, impervious, and resistant to water and chemicals used in their sanitation.

All components, including materials and finishes, must be easy to sanitize. Materials and finishes must be resistant to damage from the movement of equipment such as cage racks in the facility, or they must be protected from damage. All hollow doors and frames must be filled or completely sealed, and ledges, crevices, cracks, and unsealed service penetrations that can harbour dirt and vermin should be eliminated.

6.1 WALLS

Walls should be covered with an impervious coating (e.g., an epoxy coating) that withstands frequent cleaning and chemical disinfectants. They should be free of cracks, and all pipe and service sleeves should be sealed to exclude vermin. For ease of cleaning, the walls should be seamless, and the floor should be coved to the walls.

The most common substrates for walls are concrete block and drywall. When using concrete blocks, a medium weight should be used to achieve a dense, smooth block face. Low-density blocks are difficult to seal and leave small pores that are difficult to clean. Shallow concave mortar joints should be used for ease of cleaning. Concrete blocks can be filled with sand to improve sound attenuation (particularly important for primate and dog rooms). For walls that are not easily sealed, fibreglass-reinforced plastic panels can be used to produce an effective wall covering.

All seams must be well sealed. Metal framing should be used with drywall. Wood framing members are unsuitable for animal facility construction. The drywall should be moisture-resistant and fire-rated. There should be a smooth juncture between the wall and the upper edge of the integral cove base (i.e., no ledge).

Corridor walls are especially prone to damage due to the movement of carts, cage racks, etc., and should be protected with bumper guards or protective shields. Care should be taken to select bumper guards that can be easily and thoroughly cleaned and will not harbour vermin.

6.2 FLOORS

The base floor for animal facilities should be concrete slab. The expansion joints in the concrete should be located under walls wherever possible.

Seamless epoxy flooring with an integral cove base is the most common flooring used, especially in animal rooms. It is durable, impervious to many chemicals and solvent-based products, and easily cleaned. It can

be made less slippery by adding grit to the surface; however, care must be taken not to make the surface too rough as this will reduce the lifespan of the floor and make sanitation more difficult. Toxic fumes are released during installation and repair, and evacuation of the area during the repair process is advised.

Methyl methacrylate is often used as an alternative to epoxy due to its quick curing time and the reduced time of exposure to toxic fumes.

Sheet vinyl with heat-welded or chemically welded seams is also used in animal facilities, especially in corridors. It is available with an integral cove base, non-slip surface, and antibacterial properties. Sheet vinyl is comfortable to walk on and reduces noise levels. It tends to stain and mark more easily than epoxy; however, it is easily repaired if damaged, and the process does not require evacuation of the area, as toxic vapours are not produced.

Paint or sealing on a concrete floor generally wears off, requires frequent refinishing, and does not provide a non-slip surface. In addition, the rubber or vinyl cove bases often associated with these types of finishes may provide a refuge for vermin.

If other floor types are considered for use, they should be investigated closely, including a review of their use in other facilities. If possible, they should be tested before being used extensively in a facility.

6.3 CEILINGS

As with floors and walls, ceilings must be resistant to frequent washing and disinfection; however, they are not subject to the same wear and tear. The preferred material for ceilings is moisture-resistant drywall that is well sealed at all ceiling-wall joints and penetrations. Ceilings should be coated with a two-stage epoxy finish or high-quality enamel paint. It is easier to patch enamel if required, but overall, enamel is less durable. All animal and procedure rooms should have seamless ceilings.

Where it is necessary to have access to mechanical and electrical services in the space between the ceiling and the roof or the floor above, these services should be located above hallways, rather than in animal rooms (as noted in Section 5.8, "Mechanical and Electrical Space and Distribution of Services"). Access hatches to above-ceiling infrastructure, with appropriate sealing, should be used.

The underside of concrete slabs should not be used as ceilings with no sub-ceiling; it may be difficult to clean, and the exposed pipes and mechanical services tend to collect dust. These ceilings may also be subject to corrosion from high moisture levels. At a minimum, concrete must be sealed with purpose-made products to prevent continuous surface erosion and dust formation.

6.4 DOORS

Doors in animal facilities must be of high quality and resistant to physical impact. Doors and frames should be made of durable metal and be completely sealed or filled with foam to prevent access to insects. The frames should fit within the wall space, rather than overlapping, so that there are no ledges to collect dust. The doors should be large enough to accommodate the movement of all equipment that could potentially be moved through them; this includes sufficient space to accommodate the replacement of large equipment, such as a cage washer, when needed. The minimum sizes are 120 cm nominal opening for a single door and 180 cm nominal opening for a double door. To protect doors from damage, it is often necessary to cover at least the lower half with sheet stainless steel, aluminum, or plastic. Where excessive damage is anticipated

due to the type of equipment being moved through the doors, consideration should be given to bumper guardrails. A door sweep should be installed on the base of the door if the clearance exceeds 3.2 mm.

Windows in doors are useful to allow observation into rooms and as a safety feature. Where animal rooms or procedure rooms are small, windows help make the space less claustrophobic. Windows on animal room doors do not have to be large (e.g., 15 x 20 cm); however, larger windows in doors may be useful (see Section 6.5, "Windows"). Window covering should be available to block external light or movement, as required. If a screening device is incorporated into the door structure, it should be well sealed so that it does not harbour vermin. Opaque magnetic sheets can be used effectively to occlude small windows. Larger windows can be temporarily blocked out with caulked plastic laminate when necessary.

Guideline 38

The direction in which doors swing must be in accordance with building codes and should be such that they are safe, do not impede traffic flow, and complement the control of airflow where required.

Generally, doors should swing into a room rather than out into a corridor. However, if there is limited traffic within a corridor or doors will be opened infrequently, opening doors into the corridor may allow more efficient use of space within a room or anteroom. Doors in relatively close proximity, such as those in an anteroom, should both swing in the same direction or, if necessary, out from the anteroom such that only one door needs to be opened at a time. Interlocking doors are often useful to ensure only one door is opened at a time. Where the pressurization requirement with respect to the door swing is contrary to the building code, a dispensation may be required.

For self-closing doors to work effectively, it is usually necessary for them to close in the direction of airflow. However, in a biocontainment facility, doors should open with the airflow and close against it, particularly where the doors are between areas of different biocontainment statuses or air pressures. This prevents aerosols and contaminants from moving from contaminated to clean areas by the vacuum created by opening the door. This is also the direction of swing that will have the least effect on the airflow patterns. The effective function and safe use of a door should dictate its direction of swing, which in turn may require compensating mechanical devices to make doors work effectively (e.g., stronger self-locking devices, interlocking doors, and warning lights).

If the animal facility will be used by a large number of investigators, the doors should have locks that can be individually keyed, keypads, proximity reader access control, or similar devices.

6.5 WINDOWS

Windows to provide natural light are encouraged, providing the temperature of the room can be well controlled (i.e., no temperature fluctuations), there is no interference with the lighting requirements of the scientific activities that will take place, and security risks are addressed. Natural sunlight is beneficial to humans and animals; however, windows can pose difficulty in controlling internal environments and security concerns. Temperature fluctuations due to radiation, conduction, and convection can be quite extreme.

Windows may be incorporated into outside corridors or rooms for personnel, provided all security concerns are met and the windows are well sealed. Interior windows between rooms, or between rooms and corridors,

often open up an enclosed space. They can be useful in areas for personnel and in surgical suites to maximize visual communication. Non-breakable windows with metal frames should be used, and the frames should be flush with the walls or recessed.

6.6 CABINETS AND OTHER FIXED EQUIPMENT

Guideline 39

Cabinetry in an animal room should be limited to that which is essential for the proper functioning of the room.

Only essential equipment should be built into animal rooms to facilitate cleaning and reduce the potential for harbouring unused supplies and vermin. Cabinetry and sinks should be well sealed to the walls.

All materials and finishes must be durable, impervious, and resistant to water and chemicals used in their sanitation. Stainless steel is the preferred material. Some epoxy-coated metal or plastic finishes may be acceptable, but these should be thoroughly investigated and, where possible, tested before use throughout the facility. Wood does not fully meet the above criteria.

Mobile stainless-steel equipment that can be thoroughly sanitized between projects should be considered, as this enhances the versatility of space utilization. Portable sanitizable cabinetry should also be considered.

7 PLUMBING AND ELECTRICAL CONSIDERATIONS

7.1 PLUMBING

Guideline 40

The plumbing system must supply water of the appropriate quality to where it is required, to meet the needs for animal and human consumption, sanitation, personal hygiene, and the operation of safety equipment.

Water quality requirements depend on the intended use. Examples of water requirements throughout the facility include the following:

- Potable water of consistently high quality must be available within the animal facility for both animal and human consumption (Government of Canada, n.d.).
- Water of an appropriate quality must be available for all safety equipment, such as eyewash stations, emergency showers, and fire sprinkler systems; in particular, potable, temperature-controlled water is required for eyewash stations.
- Ample hot and cold water must be available throughout the facility for sanitation purposes and showers for personnel.
- Grey water can be used for toilets.

Consideration must also be given to how water requirements for important functions can be addressed in potential disaster scenarios.

Guideline 41

Drains must be strategically located in areas where water may be used extensively for cleaning. Drains should be designed to be sealed when not in use or equipped with manual or automatic flushing systems.

The type of piping for drains and the size and depth of the P-trap depend on the service area. For example, pipes for cage wash and procedure rooms need to be temperature- and acid-resistant. This also applies where acidified water is flushed from an automatic water system. The *Canadian Biosafety Standard* (Government of Canada, 2022) and local and provincial or territorial regulations must be consulted to determine whether effluent treatment is required.

7.1.1 Drinking Water

When designing a new animal facility or retrofitting an established one, water quality is one of the major criteria that will contribute to positive animal welfare and reliable scientific results. The quality of municipal and well water supplies is very site-specific. The quality of municipal water can be confirmed by municipal procedures; however, water from a well needs to be analyzed.

The need for water treatment and type of treatment should be selected with consideration of the effects on the animals and the scientific activities, as some methods can affect the health and physiology of the animals (Fidler, 1977; Hall et al., 1980; Hermann et al., 1982). For example, in some situations, important minerals are removed when reverse osmosis is used, and they need to be added back into the water. Possible water treatment systems include pre-filtration, ion exchange systems, ultraviolet irradiation, ultrafiltration (0.5 microns), and reverse osmosis.

7.1.2 Plumbing for Animal Rooms

Guideline 42

All animal rooms and their anterooms should have a stainless steel, hands-free sink, preferably near the door.

Every animal room and associated anteroom should be supplied with hot and cold water and a stainless steel, hands-free sink for washing hands. The sink should be located relatively close to the door to allow hand washing upon entry and exit.

Drains for sinks must be sealed such that waste water cannot be aerosolized into the animal room. It is advisable to have a hose connection as well, especially in large animal rooms. There are built-in hose bibs specifically designed for animal facilities (see Diagram 13).

Floor drains are required in rooms intended to hold animals larger than rodents. They should be a minimum of 15 cm in diameter and contain flush systems. They may be incorporated with floor trenches, depending on the intended method of housing the animals. Floor drains are not required in rodent rooms, although they may be useful during major cleaning between groups of animals and as a precaution against flooding where automated watering systems are used. If floor drains are used in rodent rooms or corridors, they should be a minimum of 10 cm in diameter and incorporate running traps with cold water primer lines or a manual or automatic flushing system (see Diagram 14). All floor drains should be designed to prevent backflow.

All floors should slope towards drains.

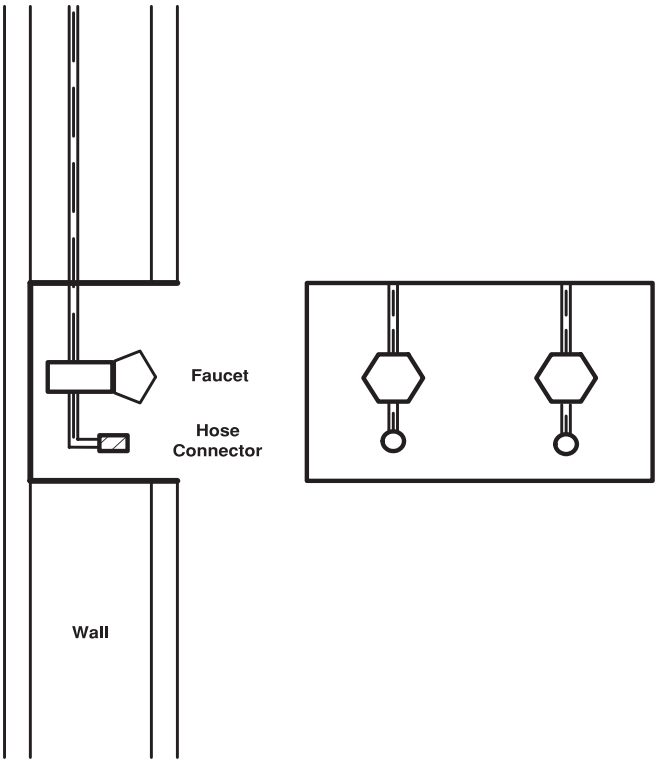


Diagram 13 Recessed hose bib detail

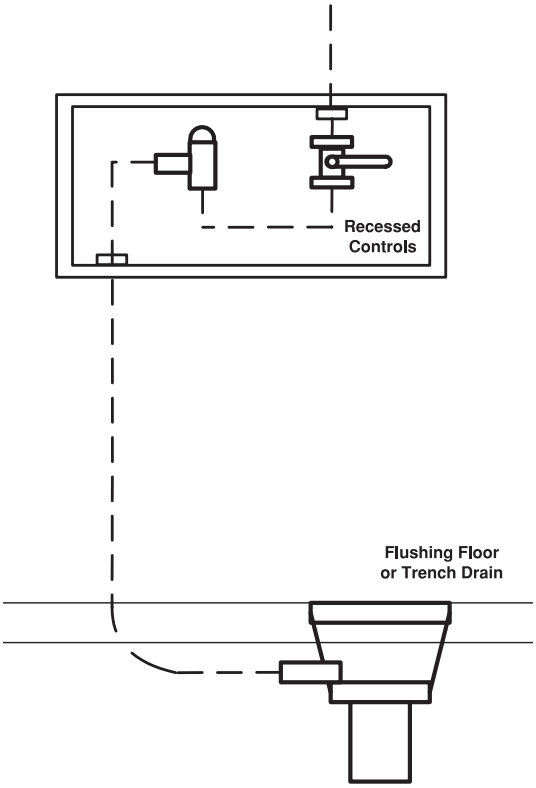


Diagram 14 Flushing drain pipe

7.1.3 Plumbing for Procedure Rooms

Animal preparation areas, surgical suites, necropsy areas, and other specialized areas require plumbing specific to the equipment to be used. The supplier of the equipment should be consulted prior to installation of the rough plumbing. Sinks should be hands-free to minimize cross-contamination.

7.1.4 Plumbing for Cage Wash and Sterilization Areas

Cage washers, bottle washers, sipper tube washers, autoclaves, etc. have unique plumbing requirements that must be designed in consultation with the supplier of the equipment.

Large double sinks are often included on the dirty side of the cage wash area for the disposal of urine and the rinsing of cages. It may also be necessary to have a very well-drained bay or alcove for hosing down large pieces of equipment that will not fit in the cage washer or that require a preparatory pre-rinse.

7.1.5 Plumbing for Personnel Areas

Washrooms and showers should be designed with sufficient capacity to accommodate the needs of personnel and should be easy to sanitize. Sinks with hands-free faucets should be included in personnel rooms and washrooms.

7.2 ELECTRICAL

7.2.1 Electrical Outlets

Electrical outlets should be strategically located throughout the facility to accommodate all portable electrical equipment that is expected to be used without requiring the use of extension cords.

The number of electrical outlets in a room should be based on the potential use of equipment in that room (e.g., ventilated cage systems, change hoods) to meet current and future demands. Outlets must be located so they are easily accessible to people using the rooms, but not to the animals held within (i.e., they should not be located within the animal pens unless suspended from the ceiling and out of the animal's reach).

Guideline 43

All electrical outlets in animal rooms, and in other areas where they may be exposed to water, must have a ground fault interrupter (GFI) and be fitted with an all-weather cover.

All electrical conduits through walls must be completely sealed to eliminate their potential use as routes for vermin or aerosols.

7.2.2 Equipment

The power for equipment (cage washers, autoclaves, surgical lamps, automated plumbing units, etc.) must be sized and installed according to the manufacturers' recommendations. Some specialized equipment, such as that used for imaging and behavioural studies, has a particularly large power draw or specific requirements for clean power.

7.2.3 Light Fixtures

All light fixtures in animal rooms, the cage wash area, surgical suite, and other areas that may be exposed to water or high humidity should be vapour-proof. All other light fixtures in the facility should also be sanitizable and vapour-proof to facilitate cleaning. For information on types of lighting, see Section 8.2, "Light".

The location and spacing of light fixtures should aim to achieve an even distribution of light in animal rooms. This will be influenced by the layout of enclosures. For cage racks, the light intensity on the top shelf may be considerably higher than that within the shelves, and it may be necessary to avoid placing animals in cages on the top shelf, thus affecting the number of cages in the room. However, maintaining empty cages with bedding materials on the top shelf can decrease the likelihood of a confounding cage effect.

Ballasts, timers, and other electronic equipment associated with lighting systems emit ultrasound and infrasound in the range audible to laboratory animals, which could disturb the animals and impact certain types of scientific activities. Therefore, lighting equipment that does not produce high levels of such sounds should be sourced.

7.2.4 Monitoring and Communication Systems

Electrical and wiring requirements must support the facility's systems for environmental monitoring, security, and communication. These systems are discussed in Section 8, "Environmental Monitoring and Control", and Section 10.3, "Security System".

7.2.5 Emergency Power

Guideline 44

An emergency power source must be available to support life-sustaining equipment in all facilities holding animals.

To maintain the health and well-being of animals during power outages, it is essential that critical functions be supplied with emergency power. Ventilated racks should be on emergency power, and ventilated racks with sealed cages (e.g., biocontainment and gnotobiotics) must be on emergency power. A reduction of 50% of the air supply for short periods of time may be acceptable; however, the maintenance of air pressure differentials is essential, especially in containment areas. Sufficient emergency lighting must be available to permit personnel to function safely in the animal facility and to minimize the impact on the circadian rhythm of the animals. The surgical suite must be supplied with sufficient power to allow the completion of surgeries during a power outage. All equipment requiring electricity that could be in use during a surgical procedure must be on the emergency power supply; this includes such items as a portable x-ray unit, basic equipment, lamps, respirators, electrocauterizers, and equipment to keep animals warm during and after surgery. Emergency power may also be required to maintain the security system and building automation system.

The most common source of backup power is a diesel-powered electrical generator. The fuel holding tanks should be capable of holding enough fuel to run the generator for a minimum of 24 hours. Generators powered by natural gas are also used but are dependent on a constant gas supply and are therefore less independent than diesel-powered generators. Propane is a gas alternative that can be stored. Electrical generators are very noisy and require careful positioning with sound and vibration isolation relative to the animal facility. Co-Gen projects can also be used to supply emergency power.

8 ENVIRONMENTAL MONITORING AND CONTROL

Guideline 45

Each animal room should be equipped to monitor temperature, relative humidity, and differential pressures.

Environmental sensors in animal rooms should ideally be linked with the building automation system for real-time monitoring and alarms that provide notification to remote locations. Where this is not possible, stand-alone devices can be used to record temperature and humidity. If automatic monitoring systems are used, personnel should still be able to check the environmental conditions when in the room. This would provide personnel with current information and allow for a quick response if an issue arises.

Devices should measure temperature at approximately 90 cm from the floor. Temperature sensors for activation of reheat coils are commonly located in the exhaust duct close to the animal room. This, in effect, reads the total of the temperature of the supply air plus heat gain in the room. Humidity can be recorded in the supply air duct.

Differential air pressures should be monitored on a regular basis to ensure the correct direction of airflow within the various sections of the facility. This is extremely important for barrier units. Permanently fixed air pressure recording devices can be useful to record differential pressures between animal rooms and adjoining rooms or corridors. However, it may be more practical and effective to measure the actual direction of air movement between these areas. Information on differential pressures can be found in the National Institute of Health's *Design Requirements Manual* (NIH, 2019).

The ability to control the environment within an animal facility is critical to the well-being of the animals, the comfort of personnel, and the validity of the scientific activities. Environmental factors comprising challenges to the facility design are described in the following sections.

8.1 SOUND AND VIBRATION

Guideline 46

Equipment and activities that generate noise and vibration should be isolated from the rest of the animal facility.

Rooms intended to house animals that are sensitive to noise and vibration, such as rodent breeding colonies, should be located as far away as possible from noise- and vibration-generating equipment or noisy animals, or protected by sound attenuation measures within the room. For information on the impact of noise and vibration on particular species, see the CCAC types of animal guidelines.

Excessive noise (including high-frequency noise beyond the level of human hearing) and vibration can be irritating and, in some cases, detrimental to animal and human health. The animal facility is full of sounds and vibrations during the active part of the day, superimposed on the continuous baseline noise associated with HVAC systems. Cage washers and sterilizers, hoses, high-pressure sprays, and the movement of equipment and cages all generate noise. Certain animals generate considerable noise (e.g., nonhuman primates, dogs, and pigs), and human voices and activities can add substantially to the noise level. In addition, noise from the room can amplify inside cages.

Even though nonhuman primates, dogs, and pigs produce loud noises, there is evidence that persistent loud noise levels are not good for their health. Therefore, rooms for these animals should be designed to minimize the expression of noisy behaviours and increase the expression of calm, quiet behaviours (e.g., by providing space to house them in small groups), both for their health and for the health of personnel and other animals housed nearby. Anterooms may also act as sound locks and assist in sound attenuation and isolation, particularly when housing noisy species.

Whenever possible, the frequency of the sound emitted by alarms used in the animal facility should be in a range that does not affect the animals. Low-frequency fire alarms are very effective (Clough and Fasham, 1975). Visual alarms may be used as an alternative in some cases. Alarms that can be tested, as required by law, without emitting acoustic output should be used.

Intercom systems can be disturbing to animals. These systems should be eliminated from animal rooms and test rooms (particularly behaviour testing rooms) or muted if deemed necessary (e.g., an emergency communication device in a high-containment-level suite).

Guideline 47

Sound-reducing features should be incorporated into the building structure.

Mass in the building structure is important in attenuating sound. Strategies to control sound include filling concrete block walls with sand or grout, hanging heavy plastic sound baffles in open spaces, and using composite sound-absorbent panels. Any materials used should be sanitizable.

8.2 LIGHT

Three aspects of light in animal facilities should be considered from the perspective of the well-being of both animals and personnel: photo-intensity, photoperiod, and spectral quality.

8.2.1 Photo-Intensity

Guideline 48

The light intensity for animal rooms should be suited to the species that will be housed.

Information on the impact of lighting on particular species can be found in CCAC types of animal guidelines. A light level of 325 lux at one metre above floor level was generally considered appropriate for com-

mon species of laboratory animals (Bellhorn, 1980); however, it is now thought that this may be too high (De Vera Mudry et al., 2013). Also, measuring photo-intensity in the centre of an animal room does not take into account the overall light distribution throughout the room, nor does it address the position and distribution of the cages relative to the light source.

For most animals, with the notable exception of diurnal sight-oriented mammals (e.g., greyhounds), low light levels do not present a problem. Bright light, however, should be avoided. Animals with non-pigmented irises, such as albino rats and mice, white pink-eyed rabbits, and some guinea pigs, are not able to accommodate more intense light levels.

The intensity of light required for personnel to carry out daily activities in an animal room is often too bright for the animals and may cause retinal damage. Therefore, lights should be designed so they can be set at different intensities, especially in rooms for rodents, albino animals, and some avian species (see Section 8.2.3, "Spectral Quality", for more information on light sources).

Where task lighting for people is needed in the animal room, it should be restricted in its dispersion, and the period of increased light levels should be minimized. Levels of around 1000 lux (90-foot candles) provide adequate task lighting if used judiciously, and an override control can permit increasing the intensity up to this level for a limited period. Variable-intensity light controls can be used to provide light intensities suited to the animals and personnel. The Illuminating Engineering Society of North America (IES, n.d.) provides resources that can assist with designing appropriate lighting.

8.2.2 Photoperiod

Guideline 49

Diurnal light cycles in animal rooms, including the crepuscular periods of dawn and dusk, should be controlled and monitored centrally, with alarms linked to the building automation system.

Consistency in the diurnal cycle is often critical to animal health and reliable results for scientific activities. Animals' endogenous rhythms can be significantly skewed if the dark phase of the cycle is interrupted. Therefore, windows to animal holding rooms should be designed so they can be blocked when necessary. Window closures can be built into the door, or opaque magnetic covers can be used.

If nocturnal animals are to be housed, reversed light cycles may be needed to facilitate working with these animals during normal working hours.

The crepuscular periods should be simulated by a slow transition when lights are turned on and off.

8.2.3 Spectral Quality

Guideline 50

The wavelength of light should simulate the natural wavelengths of sunlight as closely as possible.

For most laboratory animals, the range of light wavelengths that promote positive welfare is similar to natural sunlight (300-2,000 nm, with the majority clustered between 450-700 nm). For example, lack of ultraviolet light has a negative effect on the welfare of rats, and providing artificial full-spectrum light at a low light intensity, combined with sufficient shelters or nesting options, is important (Sørensen, 2014).

The human visible spectrum is 390-750 nm. Lighting, particularly its spectral quality, affects the work performance of personnel (Al Horr et al., 2016).

Plastic cages used to house most rodents may alter the wavelength and intensity of light that the animals receive, especially if the cages are equipped with filter caps (Dauchy et al., 2013). This should be considered from the perspectives of animal welfare and minimizing variables.

8.2.3.1 Light-Emitting Diodes

Light-emitting diode (LED) illumination compares favourably in biological effects with other sources of lighting. The advantages of LED lights include energy efficiency, solid state, long life, a wide range of spectral control, low heat production, and a mechanical size advantage (Dauchy et al., 2016).

LED lighting has been deemed safe for use with laboratory rats, and since the rat has been regarded as the laboratory animal that is most susceptible to phototoxic retinopathy, this provides a good indication of the overall safety of LED lights (Heeke et al., 1999). Rats exposed to blue-enriched LED light during the daytime have been found to have higher nocturnal melatonin levels than those exposed to cool white fluorescent light, and this increased melatonin has positive effects on circadian rhythm and health in these animals (Dauchy et al., 2016).

8.2.3.2 Fluorescent Light Source

Fluorescent light has a greater emphasis on violet light, which has the shortest wavelength on the visible spectrum, and is thus more closely aligned with sunlight than incandescent light.

Full-spectrum fluorescent lighting contains wavelengths in the ultraviolet range. Wide spectrum lights have been shown to contribute to better welfare for rats and hamsters (Brainard et al., 2001), and therefore, when using fluorescent lights, they should be full-spectrum.

The level of illumination in fluorescent lights deteriorates with the life of the tubes, and tubes should be changed frequently, or a diffuser should be used to maintain appropriate lighting.

8.2.3.3 Incandescent Light Source

Incandescent light emitted from a standard light bulb with a glowing filament has an emphasis on red or longer wavelengths of the visible spectrum. Although not ideal, this will provide adequate illumination.

8.2.3.4 Quartz Halogen Light Source

Quartz halogen light sources provide good illumination; however, they produce a significant heat load in the room, which needs to be effectively dissipated. This light source can be useful in simulating the crepuscular periods because of their sensitivity to rheostat control.

8.2.3.5 Light Tubes

Light tubes provide even light distribution in spaces, such as animal rooms, with the light source positioned outside the space, which facilitates servicing. The tube is designed to distribute even illumination along its length. The use of light tubes enables inaccessible spaces (e.g., large atria) to be evenly illuminated from easily accessed light emitting sources. Light tubes are also useful in illuminating restricted-access areas, such as biocontainment suites, and in renovating areas with very limited floor-to-floor distances. The units can be used horizontally or vertically.

Light tubes using metal halide lights generate significant levels of heat as well as light. However, LED sources can be integrated to improve energy efficiency.

8.3 HEATING, VENTILATION, AND AIR CONDITIONING

Air quality within an animal room and each animal enclosure is affected by the frequency of air changes, the type of enclosures, other equipment in the room, the species and other characteristics of the animals being housed, and the husbandry practices (e.g., type and amount of bedding provided and the frequency with which it is changed). The impact of the overall HVAC system must be evaluated at both the room and cage level.

Guideline 51

HVAC systems should provide a healthy and comfortable environment for the animals and for personnel working in the facility and should be stable, so that the system does not contribute significantly to experimental variability.

The HVAC system should supply clean air at a specific temperature and humidity to the animals housed within a room and should exhaust all contaminated air. Environmental parameters should be controlled at both the room level (macro-environment) and the cage level (micro-environment). For guidance on air quality in the micro-environment, see the CCAC's types of animal guidelines.

Guideline 52

HVAC systems in laboratory animal facilities must operate continuously, 24 hours per day, year-round.

Because the welfare of the animals and the validity of scientific results depend on the continuous operation of the HVAC system, it is critical to have sufficient capacity to operate them at all times and contingency plans for power outages (see Section10.4, "Redundancy"). Generally, all conventional animal room spaces should be supplied with at least 50% of its normal air turnover during short cutback periods of less than 12 hours. It is critical that differential air pressures are maintained for inclusion and exclusion zones. Duplication of fans and an alternative electrical power source to maintain the operation of the balanced system to an appropriate level are mandatory. Containment facilities require exhaust fan redundancy (Government of Canada, 2022). HVAC systems for laboratory animal facilities may therefore make up 40% or more of the total construction costs.

8.3.1 Temperature

Guideline 53

The temperature of each animal room should be controlled separately in a manner that minimizes fluctuations.

The temperature requirements for each room depend on the species (see the CCAC's types of animal guidelines for temperature requirements of commonly held species) and are influenced by the type of enclosure and bedding, as these affect the animal's ability to control its environment. For example, if animals are to be held in stainless-steel cages with non-contact bedding, rather than in plastic cages with contact bedding, higher room temperatures are usually required due to differences in insulation and air movement within the cage. Temperature requirements are also affected by the amount of heat produced by the animals, which varies with the species and number of animals present.

The most common method of controlling temperature is by bringing cooler air (i.e., 12-14°C) to the room level. The air for each individual room is brought to the preselected temperature by means of a reheat coil immediately before it is distributed to the room. The reheat system is controlled by monitoring the temperature of the air as it leaves the room, which constitutes the sum total of the heat of the air supplied plus heat gain in the room from animals and equipment motors (e.g., fan motors on ventilated racks and in biosafety cabinets). It is important to note that reheat coils supplied from manufacturers are set to fail 'on'; however, in animal facilities, they must be set to fail in the 'off'' position.

As noted in Section 6.5, "Windows", windows are encouraged in animal rooms, providing temperature requirements, as well as the requirements for lighting and security, can be addressed. Cold winter temperatures and warm summer temperatures both create temperature gradients within facilities due to conduction and convection, which makes it difficult to maintain a consistent temperature throughout the room. In addition, animals in the room may absorb or lose considerable amounts of heat by radiation, depending on their location relative to the window.

8.3.2 Relative Humidity

Guideline 54

Relative humidity should be maintained between 40% and 60% and controlled to ± 5%, depending on the species in the animal room.

The relative humidity may be controlled at the suite level rather than on a room-to-room basis. Most animals are naturally suited to 40-60% relative humidity, and their welfare may be negatively impacted if the relative humidity is less than 35% or greater than 70%. The relative humidity should be kept consistent (± 5%). The capacity to provide supplemental humidification should be available where low relative humidity is an animal welfare concern. Consideration must also be given to design requirements where animals require specialized conditions (e.g., torpor for amphibians).

During the winter, humidity may cause moisture problems and damage to the building structure due to condensation on colder external walls. Therefore, animal facilities must be extremely well-insulated, or all animal rooms should be located in the core of the facility, surrounded by a corridor or service areas with one outside wall and with lower humidity levels.

8.3.3 Air Intake

Guideline 55

Animal facilities should be supplied with 100% clean air that is sourced from outside of the building. There should be no cross-contamination of incoming air with exhaust air, and air should not be recirculated within the facility.

Clean air[1] should be available to all animals at all times. The facility air intake should be positioned to ensure that exhaust air from the facility or from adjacent buildings is not drawn into the facility. The positioning of the air intake and its relative position to the facility exhaust and surrounding structures should be subjected to fluid dynamic studies. In some cases, sufficient information may be obtained from computational fluid dynamics. However, in other projects, it may be necessary to have wind tunnel tests performed on topographical scale models of the site and surrounding buildings, with proposed air intakes and exhausts in different locations. The costs of these studies relative to the overall design and construction costs are small, and their contribution to effective and safe function in all meteorological conditions far outweighs the expense.

Each building has a cloak of air, known as the building envelope, which interfaces physically with the structure to the extent that it does not follow the movement patterns of air further away from the building. Contaminants released into the building envelope may migrate to other points on the surface of the building, for example, an office window, a door, or the air intake for the animal facility. Fluid dynamic studies will guide good design features to minimize contaminant intake.

All incoming air is filtered into the facility to remove large particulates. Where the quality of the incoming air is not consistently clean enough due to pollutants, it may be necessary to use more sophisticated filters such as charcoal and HEPA filters. The quality of air in high-density urban areas should be evaluated, and appropriate systems should be incorporated.

8.3.4 Air Exhaust

Guideline 56

Air must be exhausted efficiently so that the contaminants in the facility environment do not accumulate beyond acceptable levels.

1 Clean air is defined as meeting the supply air target values noted in Section 9, "Air Quality Performance-Based Standards": 0 ppm ammonia, 350-600 ppm carbon dioxide, <28.2 million particulates (PM 2.5)/m^3, and 0 ppb total volatile organic compounds.

Animals contribute carbon dioxide, moisture, ammonia (from urea), and allergens to the air. This contaminated air must be efficiently removed from enclosures and rooms so that it does not accumulate. Direct air exhaust is preferred.

In rooms designed to quarantine animals or contain biohazards, efficient filters, such as HEPA filters, should be used. The exhaust system should be tightly sealed to eliminate the potential for contaminating other areas. As noted in Section 8.3.3, "Air Intake", the external building exhausts should be located so that exhausted air will not enter other intakes. A local air distribution study should be conducted at the building site.

For economic and environmental reasons, it is best to reclaim as much energy as possible from the relatively large volumes of exhaust air vented from the facility. Any system of heat reclamation should be compatible with the overall design of the HVAC system.

8.3.5 Air Quality

Guideline 57

Institutions must ensure clean air is available to all animals and personnel at all times.

To maintain air contaminants below acceptable levels, the HVAC system should be capable of supplying and exhausting 15-20 air changes per hour. However, consideration must be given to the efficiency of air distribution in the room, the number of animals held, and how they are being held. Institutions that choose to operate below 15-20 air changes per hour must provide the infrastructure, monitoring, control mechanism, and documentation necessary to ensure appropriate air quality at all times for animals and personnel. For details, see Section 9, "Air Quality Performance-Based Standards".

Ideally, HVAC systems are designed to allow the number of air changes to be altered according to how the room is being used; however, this flexibility must be weighed against the potential for air balancing problems.

8.3.6 Air Distribution

The provision of clean air requires well-distributed movement of air within the room without causing drafts for the animals that may affect their ability to maintain their body temperature. Diagrams 15a) and 15b) show two possible setups for room air intake and exhaust. The air capture and containment system (see Diagram 15b) uses four-way air diffusers on the underside of a central longitudinal ceiling soffit to create a capture hood effect on either side of the soffit. The exhaust registers are located on each side of the soffit.

One goal of the ventilation system is to minimize the concentration of allergens in the environment. Laboratory animal allergens are not readily removed with traditional animal room ventilation. The standard 15-20 air changes per hour delivered and removed by conventional methods (not laminar flow or mass air displacement systems) serves to keep the most hazardous allergen-bearing particles between 5-10 nm evenly suspended and distributed. Swanson et al. (1990) demonstrated that rats produce allergens at a high rate, and it was estimated that 125 air changes per hour would be required to effectively control airborne rat allergens, which is beyond the capability of conventional ventilation systems. In order to effectively control allergens, a system of mass air displacement or negatively ventilated cages should be used.

Free-standing, recirculating HEPA filter units have a high air turnover rate. They act rapidly and can be used effectively to reduce airborne particle burdens, including allergenic contaminants. Portable units are very useful in areas such as surgical suites or for establishing cleaner environments in conventional animal units or research laboratories.

When designing new air distribution systems or new room configurations, the air distribution within the room should be tested using room mock-ups with equipment in place, prior to construction. Computational fluid dynamics allow air movement within the animal room and thermal dynamics to be predicted and visualized, and can facilitate the study of different cage rack or pen configurations.

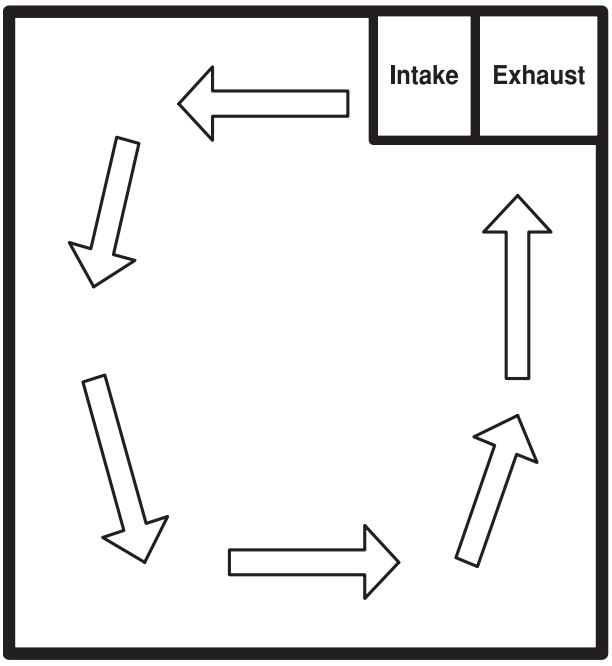


Diagram 15a One-sided intake and exhaust

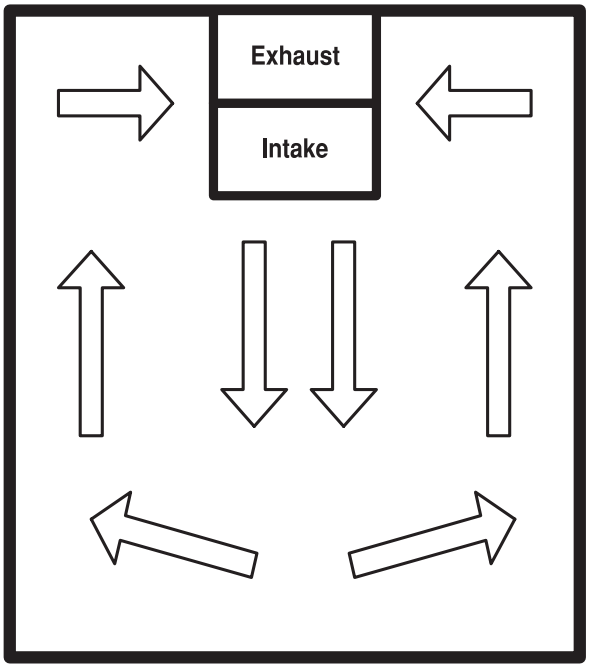


Diagram 15b Central intake and exhaust

8.3.7 Differential Pressure

Guideline 58

Differential pressures between areas of an animal facility should be set so that air flow from one area to another reduces the potential for cross-contamination.

Differential pressures between rooms and corridors are used to control the movement of air and eliminate potential sources of cross-contamination. Generally, areas that are kept at a higher pressure relative to other areas include rooms for animals with low potential to carry infection, the clean side of the cage washer, food and bedding storage, and the surgery suite. Within the surgical suite, the operating room should be positive to the preparation room, and the preparation room should be positive to the corridor. Areas that are kept

at a lower pressure to these areas include rooms for animals of unknown or compromised health status, the quarantine area, the necropsy area, the dirty side of the cage washer, and the waste storage area. Areas within exclusion barriers (see Section 5.7, "Barriers") should be under positive pressure, whereas those areas where air movement outwards needs to be limited (inclusion), such as biohazard areas, should be negative. However, when establishing differential pressures, they should also be set with a view to minimizing personnel exposure to animal allergens and any chemicals administered to the animals.

Where greater control of pressure differentials is desirable, anterooms are effective. They create an air barrier between the room and the corridor. It is common to set differential pressures in suites for exclusion to have a cascade effect, such that the air pressure decreases as one goes from the room to the anteroom, to the corridor, and then to the outside of the suite (see Diagram 16). The reverse cascade effect is often used for inclusion, such that the room is the most negative.

The cascade system of differential pressures assumes that the disease status of specific animals will always remain the same. However, many disease studies require uninfected animals that are to be intentionally infected with disease organisms, and there is also the possibility of uninfected animals becoming infected unintentionally. Therefore, in many cases, it is beneficial to consider a system that offers both inclusion and exclusion at the same time. Such a system may be established by supplying clean air to an anteroom at a pressure greater than that of both the holding room and the corridor (see Diagram 17). With proper management, the positive-pressure anteroom should provide an effective way of establishing an exclusion barrier, an inclusion barrier, and a combined inclusion and exclusion barrier.

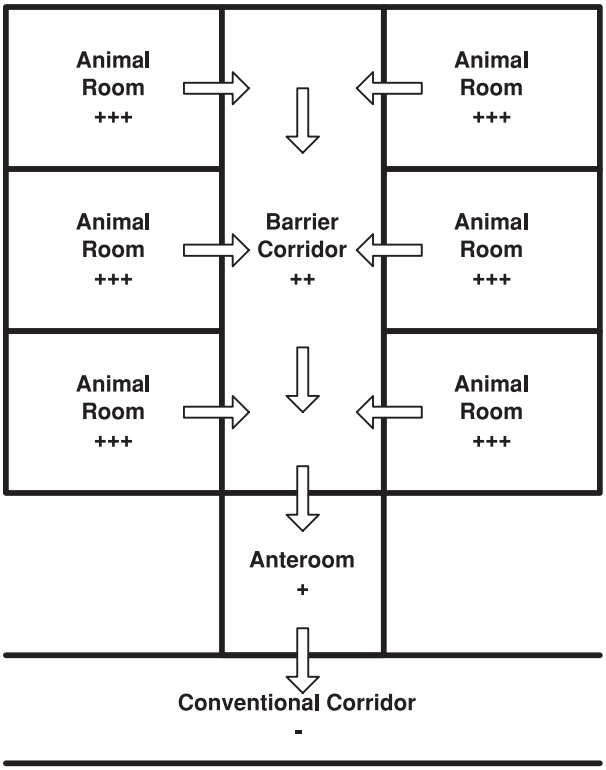


Diagram 16 Differential pressure – cascade effect

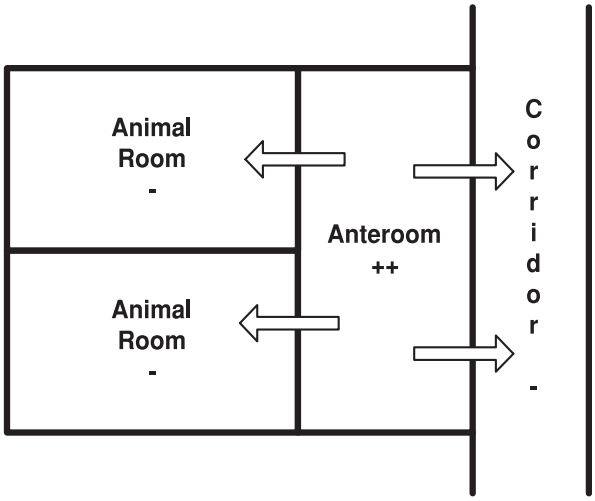


Diagram 17 Differential pressure – air barrier effect

To maintain differential pressures, doors must be kept closed, and the time that they are open must be minimized. For anterooms to be effective barriers, only one door of an anteroom can be opened at a time; otherwise, differential pressures are eliminated, thus destroying a major function of the anteroom. It is essential to have well-sealed rooms for differential pressurization to work.

Differential pressurization is very difficult to control directly, and pressures should be controlled by volumetric offset. This implies that room pressures are set by controlling the volume of air taken in versus the volume exhausted. For example, to achieve a positive pressure in a room relative to a corridor, air could be blown into the room at 500 ft^3/min and exhausted at 400 ft^3/min. Assuming the room is well sealed, the excess 100 ft^3/min would be forced out into the corridor through small cracks around the perimeter of the door.

8.3.8 Ventilated Cage Racks

Ventilated cage racks are frequently used to house rodents and may be appropriate for other small species. The various ways that ventilated racks can be incorporated into a facility have different implications on the design of the HVAC system.

A negative pressure rack (see Diagram 18) is used to protect the environment outside the cage from contaminants and potential allergens (i.e., inclusion). Negative pressure is created by forcibly exhausting the air, either by a portable exhaust motor with a HEPA filter or by connection to the room exhaust. The movement of air at the cage level is illustrated in Diagram 19. The portable motor should give good control over the rate of exhaust, and the HEPA filter should remove particulate matter, including allergens. However, unless it is connected to the room exhaust air duct, the system will contribute odours and heat from the animals and motor to the room, necessitating frequent air changes.

The use of two independent motors for supply and exhaust on ventilated racks (see Diagram 20) will allow the cages to be maintained at negative or positive pressure, provided the supply and exhaust are directly connected to each cage. Another variation of this system involves the scavenging of exhaust air from around the cage rather than from directly within (see Diagram 21). In this type of unit, the cage is kept at a positive pressure while the area surrounding the cage is kept strongly negative, thus giving both an inclusion and exclusion system if designed efficiently. Both the intake and exhaust air of these units are HEPA filtered. The heat generated by two motors per rack, as well as animal heat and some animal odours, is released into the room, thus increasing the room ventilation requirements. The room ventilation requirements can be reduced significantly by attaching the rack exhaust to the room exhaust or preferably to a dedicated exhaust.

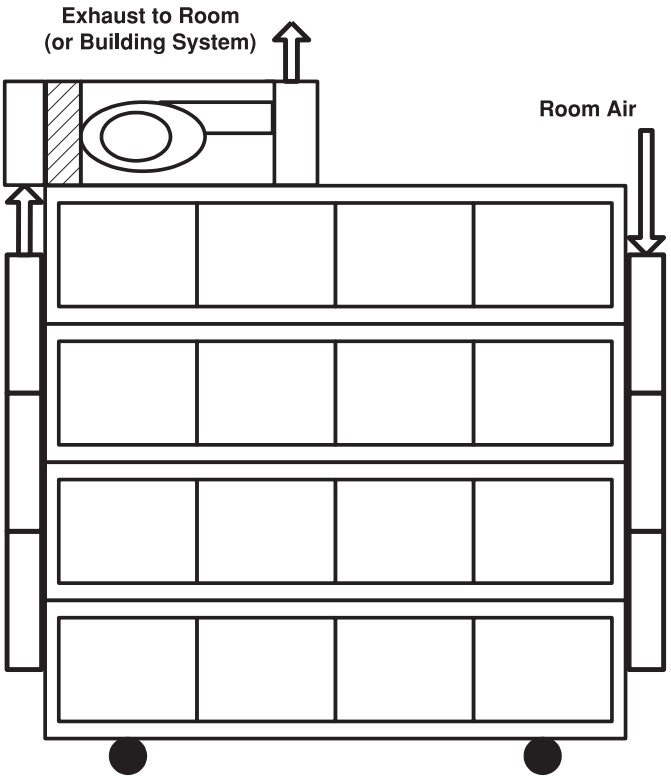


Diagram 18 Ventilated rack – negative pressure

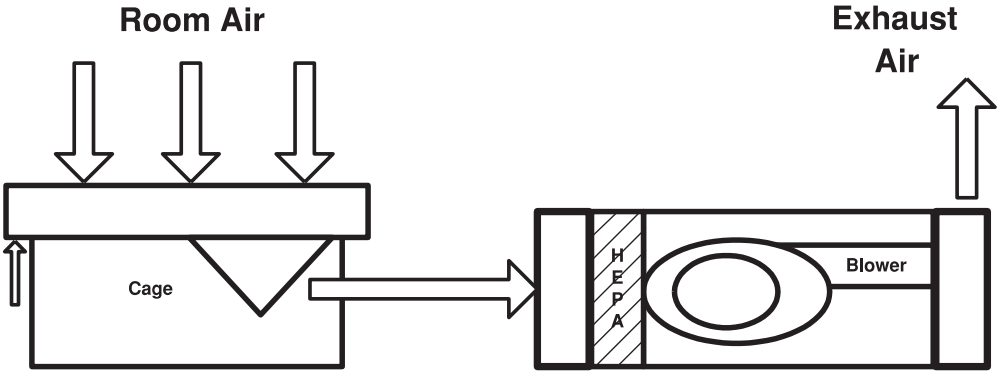


Diagram 19 Ventilated cage – negative pressure

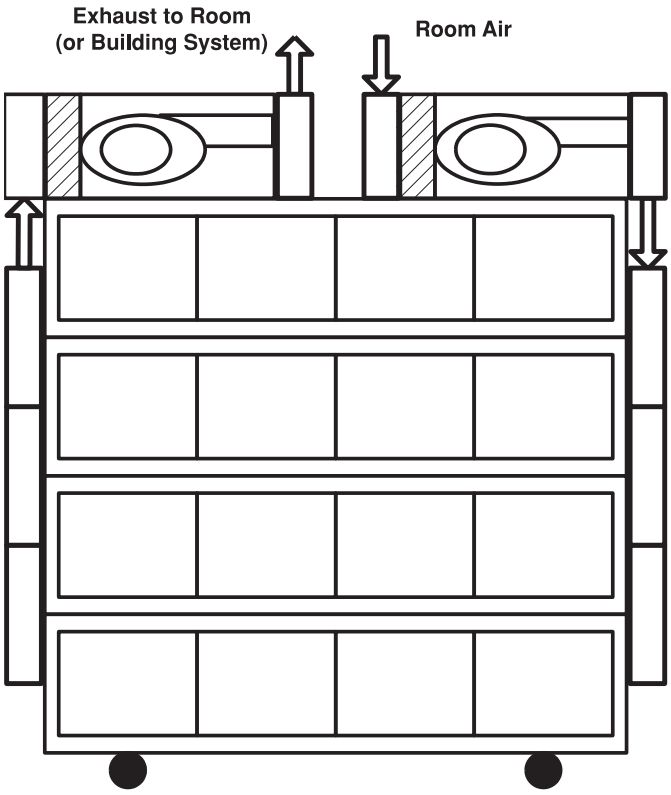


Diagram 20 Ventilated rack – positive or negative pressure

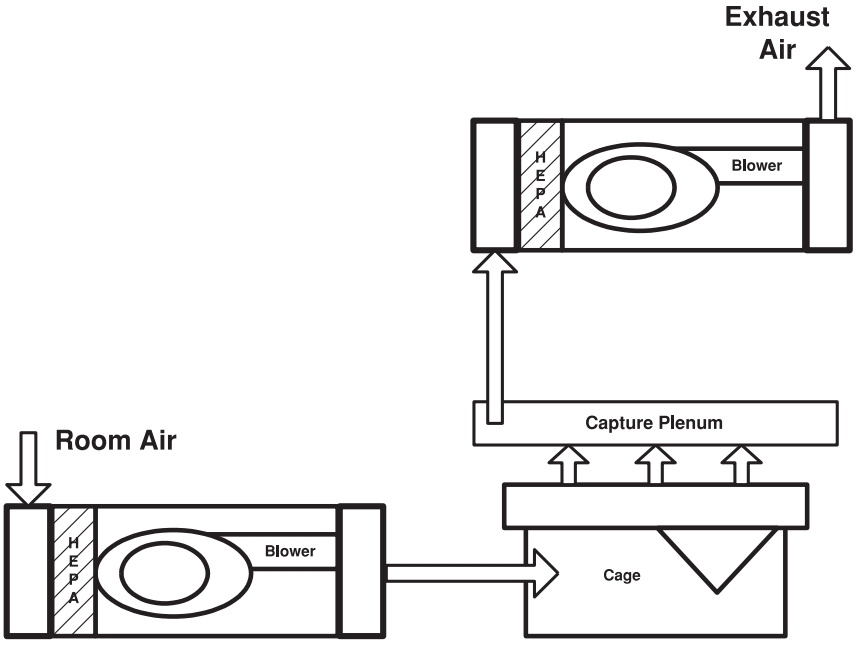


Diagram 21 Ventilated cage with scavenging system

Another type of ventilated rack is a negative pressure rack for both inclusion and exclusion that is solely dependent on the building exhaust for removing air. The air is filtered into tightly sealed cages via polyester filters and exhausted by connecting the rack directly to the room exhaust. The lack of motors in these units results in quieter systems without the additional motor heat. Because they are directly connected to the exhaust system, heat and pollutants generated by the animals are exhausted outside the room, which should enable fewer room air changes per hour.

If a room is supplied with HEPA-filtered air at positive pressure to the cages, a negative pressure rack will function effectively as both an inclusion and exclusion barrier. This setup provides maximum flexibility and safety for both the animals and personnel. However, this requires effective biosecure room entry and exit SOPs to be in place and the use of a biosafety cabinet for all animal procedures.

The fan motors operating the supply and HEPA-filtered exhaust systems on ventilated racks create noise and vibration that may seriously disturb the animals. Having these units wall-mounted and set underneath or beside the rack can attenuate both noise and vibration.

9 AIR QUALITY PERFORMANCE-BASED STANDARDS

The provision of clean air is critical in a laboratory animal facility to maintain the health and well-being of both the animals and personnel, and for consistency of research outcomes. The HVAC system plays a major role in providing stable, non-variable, clean air within the facility. The HVAC system should be capable of replacing potentially degraded room air with clean air, removing potentially harmful contaminants, heating or cooling the air to the appropriate temperature, and adding or removing humidity as required. The HVAC system is also used to maintain pressure gradients and directional air flow between rooms or parts of a facility, as necessary, to minimize cross-contamination.

This section provides air quality performance-based standards and monitoring requirements for those institutions that choose to deviate from providing 15-20 air changes per hour to a room. Diversity of room use within an animal facility may make it possible to supply clean air without requiring 15-20 air changes per hour in all rooms; however, in all cases, clean air must be maintained.

Guideline 59

Institutions that operate at less than 15-20 air changes per hour must monitor and record air quality contaminants and ensure a mechanism is in place to correct deviations from the performance standards.

Monitoring air quality is encouraged for all facilities to ensure clean air is available at all times; however, it is critical for any facilities operating at less than 15-20 air changes per hour. Regardless of the air changes per hour, temperature and humidity should be monitored, as stated in Section 8, "Environmental Monitoring and Control".

9.1 AIR RECIRCULATION

The main incentive for facilities considering air recirculation is energy savings; however, recirculated air still requires conditioning and filtering, along with increased fan power associated with filtering. Therefore, the energy savings may not be as great as anticipated. The approach of reducing air change rates through monitoring, as described in this section, significantly addresses the issue of energy savings (Sharp, 2010).

The main concern with air recirculation is cross-contamination between rooms, since filters are seldom 100% efficient indefinitely, and the risk of introducing variability in the research environment, as filters are not able to capture pheromones and various gases that are not typically monitored.

While air recirculation is rare in laboratories in general, there is insufficient evidence of this approach being used in laboratory animal facilities and the risk of cross-contamination precludes air recirculation in laboratory animal facilities at this time.

9.2 FACTORS TO CONSIDER

9.2.1 Systemic and Operational Issues

Systemic sources of room air contamination are related to the design and maintenance of the facility, the HVAC system, and the equipment being used, while operational sources stem from ineffective application of SOPs for tasks conducted within the room that affect indoor air quality. A number of systemic and operational factors that affect air quality in laboratory animal facilities are discussed in the other sections of this document. These include the type of animal enclosure (e.g., open pens, static cages, and individually ventilated cages), exhaust configuration, air distribution, requirements for pressurization and air flow to maintain barriers, the species and density of animals, equipment in the room (such as change stations), and husbandry and research activities.

As noted in Section 8.3, "Heating, Ventilation, and Air Conditioning", "the impact of the overall HVAC system must be evaluated at both the room and cage level". Air quality at the cage level is addressed in the CCAC's types of animal guidelines.

9.2.2 Episodic Issues

Episodic issues result from events that cannot be predicted and are not related to the use of good systemic and operational approaches and controls (e.g., events that occur due to improper training of an individual, human error, or broken or failing equipment). Due to unexpected problems, one or more contaminants (see Section 9.3, "Key Contaminants and Target Values") can fall outside of acceptable limits for long periods of time, unless quickly detected. Episodic events can also be very short in duration and may not be detected if air quality is monitored on a weekly to monthly basis, rather than continually. For systems that only monitor air quality periodically, this may lead to an erroneous assumption that air quality is consistently good, while there may be fluctuations that could affect the health of the animals or personnel, or the consistency of the research environment. Even a weekly analysis of air quality may not permit a fast enough response to episodic events if short-term studies are underway or the elevation in contaminant levels is great.

Minimizing the occurrence of episodic events is important for all ventilation systems; however, it is critical for systems where there cannot be a timely increase in ventilation when required (see Section 9.2.3, "Heating, Ventilation, and Air Conditioning Systems"). The use of ventilated cages and cage change stations or biosafety cabinets and adherence to animal care committee-approved SOPs for all functions occurring in a room that could affect the air quality can reduce, but not eliminate, the occurrence of episodic events.

The most effective solution to an episodic event is to increase the ventilation rate to 'flush' the room, and implement short-term measures to protect the health of the animals and personnel (e.g., personal protective equipment), as appropriate. In the case of HVAC malfunction, there should be a contingency and a crisis management plan in place to address possible animal and personnel health and welfare issues if the HVAC system cannot be brought back online within a short period of time.

Responding to episodic events through increased ventilation is most efficiently achieved through a demand-based HVAC system, in which air quality is continually monitored and the ventilation rate is automatically increased when set criteria are detected, while maintaining air pressure differentials. For systems that cannot increase ventilation rates fast enough to flush the room air following an episodic event and maintain air pressure differentials, it is safer to operate at 15-20 air changes per hour. Maintaining 15-20 air changes per

hour will allow a return to acceptable air quality standards faster when episodic events occur, than if these systems operate at a lower air change rate.

For facilities that cannot promptly increase ventilation rates in response to episodic events, any consideration of reducing ventilation rates for energy conservation must be thoroughly analyzed, based on: 1) an evaluation of the risks to the animals, people, and research projects; 2) assurance that procedures are in place and adhered to that will minimize the occurrence of episodic events and minimize their impact when they occur; and 3) implementation of an air quality monitoring program (see Section 9.4, "Air Quality Monitoring"). If consideration of these factors and the air quality monitoring of a room indicate that a reduction in air changes per hour is acceptable, a lower limit of 12 air changes per hour should be maintained in that room, given that there cannot be an automatic response to episodic events.

9.2.3 Heating, Ventilation, and Air Conditioning Systems

The operation of the HVAC system depends on how the system is controlled, the diversity of ventilation requirements throughout the facility, and the ability to minimize the occurrence of episodic events that affect air quality, as well as the capacity to promptly respond when they occur. Any changes made to air flow rates must be accompanied by verification of air quality and air pressure differentials through documented monitoring.

9.2.3.1 Types of Systems

The types of HVAC systems in current use differ in the capacity to change the rate of air supplied to and exhausted from a room. Some HVAC systems have automatic air valves for supply and exhaust that adjust to maintain appropriate differential pressures. When these systems are combined with an air quality monitoring system, the ventilation rate in each room or space is adjusted automatically according to the air quality in the space, while maintaining appropriate air pressure differentials. These systems are referred to as air quality demand-based systems.

For other systems, such as constant air volume systems or demand-based systems that are not linked to air quality monitoring, changing the rate of air supply and exhaust is done manually. This is time consuming and often requires the expertise of a mechanical technician in order to maintain the required air pressure differentials of all rooms possibly affected by that adjustment. Therefore, the ventilation rate for these systems cannot be changed promptly in response to air quality monitoring or even with routine changes in the use or number of animals in a room. For these systems, the ventilation rate in each room should be set to accommodate the largest number of animals to be held at one time and a variety of species if that is the intended use of the room. However, the ventilation rate may need to be adjusted if the use of the room changes significantly. When air change rates are altered manually, there must be assurance that clean air and appropriate air differentials are maintained through monitoring (see Section 9.4, "Air Quality Monitoring").

9.2.3.2 Diversity Factor

Diverse air exchange rates may be used within a facility provided the air quality in each room is maintained within acceptable limits (outlined in Section 9.3, "Key Contaminants and Target Values"), and the required air pressure differentials are maintained. The ability to take advantage of the diversity factor is very limited in systems other than an air quality demand-based system.

Each situation will be unique, based on facility design, species and animal density in the room, type and location in the room of caging or pens, air flow patterns, whether ventilated cage change stations or biosafety cabinets are used, and, in the case of ventilated racks, how the rack ventilation system is set up.

This diversity factor may also be used by designers to determine the HVAC capacity required. The diversity factor can incorporate factors based on the intended operation of the facility, experience on typically required air flow levels to maintain desired air quality, air flow requirements from exhaust devices such as biosafety cabinets and rack ventilation systems, and animal and equipment thermal loads.

9.3 KEY CONTAMINANTS AND TARGET VALUES

The quality of the air in a room deteriorates as contaminants are generated within the room, based on room usage and activity.

Guideline 60

The key contaminants that should be monitored and documented to assure acceptable air quality are ammonia, carbon dioxide, particulate matter, and total volatile organic compounds.

Table 1 summarizes the recommendations for these key contaminants at the room level, with the aim of providing clean air that is close in composition to fresh air. Further explanation of each contaminant is provided in Sections 9.3.1-9.3.4.

In Table 1, supply air target values refer to the air being delivered to the room. These are important targets when a ventilation system is being set up, and considerations for ensuring clean air is entering the facility are described in Section 8.3.3, "Air Intake". During operations, if the supply air exceeds these target values, an investigation of the source and corresponding steps to mitigate the situation (e.g., appropriate filters) are required.

For indoor air, the target values in Table 1 indicate the acceptable operating range. If any of the contaminants rise above this level, facilities should investigate the source of the increase of that particular contaminant and take action to reduce the level to the target value. Note that these levels assume that the indicated supply air levels are being met, and they represent the increase in levels above that supply air level. As a result, it is important to identify the source of the problem in order to take appropriate action. For example, if the increase is due to an increase in the concentration of that component in the supply air, increasing the air changes per hour will not bring the room air quality within the target value, and steps should be taken to address the quality of the supply air. However, if the source of the problem is the generation of contaminants within the room, then increasing the air changes per hour may be necessary. Therefore, consideration of the difference in contaminant levels between room air and supply air should always be part of the investigation and any control of room air ventilation rates should only be done based on measurement of the difference between the supply air levels and the room air levels.

The maximum limit value for each component in Table 1 indicates a serious problem and these values should not be reached. Whenever the target values are exceeded, there should be an investigation into the source of the increase and action should be taken to reduce contaminant levels to the target values.

Table 1 Target Values for Air Quality

Contaminant	Supply Air Target Value	Indoor Air		Method of Measurement [A]
		Target Value	Maximum Value	
Ammonia	0 ppm	<5 ppm	<25 ppm [B]	Photoionization detector
Carbon dioxide	350 – 600 ppm	<500 ppm [C]	<5,000 ppm [D]	Infrared
Particulates (PM 2.5)	<28.2 million/m^3 (<0.8 million/ft^3) <10 µg/m^3	<35.3 million/m^3 [E] (<1 million/ft^3) <12 µg/m^3	<176.5 million/m^3 (<5 million/ft^3) <60 µg/m^3	Laser particle counter Optical particle mass [F]
Total volatile organic compounds	0 ppb 0 µg/m^3	<200 ppb [E] <500 µg/m^3	<1 ppm [G] <2500 µg/m^3	Photoionization detector Gas chromatography [H]

A. The values in the table relate to the method of measurement indicated. If another method is used, the values will need to be converted for that method.

B. This corresponds to the safety standards for humans for continuous 8-hour exposure (United States Department of Labor, n.d.-a; WorkSafeBC, n.d.).

C. This is a differential value compared to the supply air provided to the room. Relatively high levels of carbon dioxide are not necessarily a health concern (as indicated by the maximum limit of 5,000 ppm (United States Department of Labor, n.d.-b; WorkSafeBC, n.d.; Deutsche Forschungsgemeinschaft, 2012)); however, an increase in carbon dioxide in the room serves as a proxy for a ventilation problem.

D. It is recognized that 5,000 ppm is the 8-hour exposure limit determined by American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and Occupational Safety and Health Administration (OSHA) (ASHRAE, 2016; United States Department of Labor, n.d.-b). Since the animals are exposed to their environment continually, 24 hours/day, the maximum value should be lower than this; however, there is no specification in the literature as to what this value should be.

E. This is a differential level compared to the supply air provided to the room.

F. This is a weight-based measure, which is supported in the literature; however, the laser particle counter is a more accessible method for use in laboratory animal facilities, and therefore the value provided for a laser particle counter was derived from the value for the optical particle mass method (Sharp, 2010). The supply and weight-based differential target value is based conservatively on the recommended design indoor air quality value for PM 2.5 of 15 µg/m^3 from Appendix C of Standard 62.1: Ventilation for Acceptable Indoor Air Quality (ASHRAE, 2016), which is itself based on the National Ambient Air Quality Standard (NAAQS) (US EPA, n.d.). There is no established maximum PM 2.5 value relating to potential health hazards, so the value listed here is meant to be a reasonable maximum value based on trying to maintain PM 2.5 levels to less than 12 µg/m^3.

G. There is no established maximum total volatile organic compounds value relating to potential health hazards, so the value listed here is meant to be a reasonable maximum value based on trying to maintain the total volatile organic compounds levels to less than 500 μg/m^3 or <200 ppb which is a widely recommended target value for total volatile organic compounds (Appendix C of ASHRAE, 2016; Sharp, 2010).

H. This method requires laboratory analysis and the value provided is supported in the literature (USGBC, 2007; Washington State Department of Health, 2003); however, the photoionization method is more accessible for use in laboratory animal facilities, and therefore the value provided for the photoionization method was derived from the value for the gas chromatography method.

9.3.1 Ammonia

Guideline 61

Ammonia levels must be maintained below 25 ppm and, in general, should not exceed 5 ppm.

Further limits on ammonia levels may need to be applied to address particular requirements of any research studies being undertaken.

An ammonia level of 25 ppm corresponds to the safety standards established for humans for continuous 8-hour exposure (e.g., ACGIH (2000); the US National Institute for Occupational Safety and Health (United States Department of Labor, n.d.-a); and WorkSafeBC Exposure Limits (WorkSafeBC, n.d.)). While experience has shown that exposure to this level for this period of time does not result in significant health problems in humans, it does not mean that it is pleasant for humans or animals. People can detect the presence of ammonia at concentrations of 1 ppm (Smyth, 1956, cited in Memarzadeh, 2004), and the smell becomes obvious at 2-3 ppm.

The production of ammonia will vary according to the species, strain, sex and density of animals, as well as some disease conditions. The concentration of ammonia in the room will also be affected by the research protocol (e.g., how frequently the cages are opened, the caging system, and whether procedures are conducted within an exhausted biosafety cabinet or ventilated cage change station).

Ammonia is produced by the action of urease-positive bacteria on urea present in urine and feces. The activity of the bacteria, and therefore the level of ammonia, is influenced by temperature and humidity (Gamble and Clough, 1976). Ammonia levels can rise exponentially (Gamble and Clough, 1976); hence, the facilities, type of enclosure and husbandry practices (e.g., type of bedding and frequency of bedding changes and cage or pen cleaning (Ferrecchia et al., 2014; Perkins and Lipman, 1995)) should be designed to ensure levels of ammonia remain within safe limits.

Ammonia can be measured with dedicated ammonia sensors or a photoionization detector type total volatile organic compounds sensor, since these devices react to ammonia as well as measure total volatile organic compounds in the room. This measurement should be done differentially with respect to the supply air since dilution ventilation can only help with the increase in ammonia levels in the room. As noted in Table 1, the supply air should be free of ammonia, and therefore the ventilation should be overridden and begin to be increased if the differential ammonia level exceeds 5 ppm. Maximum ventilation or purge levels of 15-20 air changes per hour should be provided if the differential ammonia level approaches 20 ppm.

9.3.2 Carbon Dioxide

Guideline 62

Increases in room carbon dioxide levels should be kept below 500 ppm.

An upper limit of a 500 ppm increase in carbon dioxide in a space as compared to outdoor levels (defined in Table 1 as clean air) is in keeping with the ASHRAE Standards (McLeod, 2011) and other international standards (a summary is provided by the Government of the Hong Kong Indoor Air Quality Management Group, 2003). Ideally, the increase in carbon dioxide levels in the room should be similar to that of an office building, which is typically 250-500 ppm (HC, 1995).

Outdoor air contains approximately 350-600 ppm carbon dioxide; however, this can fluctuate significantly with environmental factors. In office buildings, normal human activity can result in a carbon dioxide concentration increase of 500 ppm (HC, 1995).

Monitoring carbon dioxide is particularly important in rooms where carbon dioxide euthanasia is being performed, since carbon dioxide levels approaching or possibly exceeding the maximum health-related value of 5,000 ppm could occur without proper ventilation levels.

9.3.3 Particulate Matter

Guideline 63

The increase in particulate levels above supply air levels should be kept below 12.0 µg/ m^3 or 35.3 million particles/ m^3 (1 million particles per ft^3) as measured with an optical particle counter's 0.3 µm channel.

Particulates in indoor air originate from a variety of sources and can cause irritation to the eyes, skin, and respiratory tract. In a laboratory animal facility, the additional presence of animal allergen particulates can be of considerable concern due to the potential for repeated exposure and sensitization of animal facility personnel and researchers. Allergens typically are attached to particles and are released into the air in the presence of other particulates, such as from cage bedding materials. The presence of particulates can be used then as both a proxy for the potential presence of allergens as well as an indication of high levels of particulates that should be removed.

Concerning the relationship between allergens and particulates, the absence of particulates in the environment would indicate that there are most likely no allergen particulates in the air as well. However, the presence of particulates in the air, due perhaps to the dropping of a cage or changing of a cage without the proper use of a cage change station, could indicate the potential presence (although not the certainty) of allergen particles in the air, and therefore to be safe in all cases, extra or purge levels of ventilation should be provided until the particulates return to an acceptable level.

In terms of determining what should be measured, particle size affects how far particles can penetrate into the respiratory tract and determines the sites of possible health effects. Because respirable suspended par-

ticles less than 2.5 µm in aerodynamic diameter can reach the gas exchange region, they may present long-term health concerns. Additionally, when particles are released into the air, it is the fine particles less than 2.5 µm (also known as PM 2.5) that will be suspended for the longest periods of time, versus the larger particles that will fall onto surfaces and the floor much more rapidly.

For these reasons, PM 2.5 should be continuously monitored. Accurate real time measurements of PM 2.5 can be done for example with a laser-based particle counter able to measure particulates down to 0.3 µm in the range of 353,000 to 176,500,000 particles/m^3 (10,000 to 5,000,000 particles/ft^3). This measurement, which is for ventilation control purposes, should represent the increase in particulates in the room, not the absolute particle level in the space. This is because dilution ventilation can only impact the contaminants generated in the room and will have no impact on the source concentration in the supply air which is used for the dilution ventilation.

Differential levels of fine particles (0.3 to 2.5 µm) in the room as compared to the supply air entering the room should be less than 12.0 µg/m^3 (US EPA, 2012). For a laser-based particle counter measuring particles greater than or equal to 0.3 µm, this corresponds to a level of approximately 35,300,000 particles/m^3 (1,000,000 particles/ft^3). It is important to also note that this differential threshold level can be measured by taking the difference between individual measurements of both the supply air in the supply duct before it enters the room and the air in the room itself, or preferably after it leaves the room in an exhaust duct. When appropriate filtration is used on the supply air, the particulate count should be less than 28.2 million/m^3 (0.8 million/ft3), using a laser particle counter.

Ventilation levels should begin to be increased when the differential particle levels approach 35.3 million particles/m^3 (1 million particles/ft^3). Maximum ventilation or purge levels of 15-20 air changes per hour should be provided if the differential particle level approaches 176.5 million particles/m^3 (5 million particles/ft^3) or less.

9.3.4 Total Volatile Organic Compounds

Guideline 64

The increase in room total volatile organic compounds levels above supply air levels should be kept below 500 µg/m^3 or 200 ppb, as measured with a photoionization-detector-based total volatile organic compounds instrument.

Total volatile organic compounds of concern in animal facilities include vapours from chemicals and solvents that can often be used in procedure rooms, support rooms, and even in the animal holding rooms. Other contaminants of concern in laboratory animal facilities include beta- and alpha-pinene given off from certain bedding materials, and hydrogen sulfide given off from animal waste. Total volatile organic compounds are also of particular concern in new or renovated facilities, where the building materials and new furnishing may cause increased levels, and this should be checked prior to occupancy. As with particulates, dilution ventilation can only help with those total volatile organic compounds contaminants generated internally and not the level of contaminants coming from outdoors. Therefore, the measurement of total volatile organic compounds needs to be done differentially between the level of total volatile organic compounds entering the room in the supply air versus the actual room level, or preferably, the level of contaminant in the exhaust duct after it leaves the room.

The best instrument for accurate real-time detection of differential total volatile organic compounds levels is a photoionization-detector-based total volatile organic compounds instrument. As noted in Section 9.3.1, "Ammonia", this instrument is also capable of measuring ammonia. The best location for measuring the room total volatile organic compounds levels, if at all possible, is in the room's dedicated exhaust duct.

Ventilation should begin to be increased if differential levels exceed 200 ppb as measured by a photoionization-detector-based total volatile organic compounds instrument. Maximum ventilation or purge levels of 15-20 air changes per hour should be provided if this differential total volatile organic compounds level approaches approximately 1 ppm or less.

An additional instrument that can be used for supplemental measurements is a metal oxide semiconductor-based total volatile organic compounds sensor. This instrument is less accurate than a photoionization-detector-based total volatile organic compounds instrument, but can be used specifically for measurements of methane-based compounds, especially in large animal facilities, and methyl alcohol, if those compounds are of interest.

9.4 AIR QUALITY MONITORING

Air quality monitoring must be performed where rooms operate at less than 15-20 air changes per hour; however, it is also encouraged in rooms operating at 15-20 air changes per hour, as there can still be problems with air quality. Acceptable deviation from the recommended room ventilation rate of 15-20 air changes per hour, specified in Section 8.3.5, "Air Quality", depends on the level of air quality monitoring being conducted and the ability of the HVAC system to respond to changes in air quality as follows:

1) For rooms where there is continual monitoring (defined as once every 15 minutes or less) and the HVAC system is a demand-based system that provides an automatic response to changes in the levels of contaminants identified in Section 9.3, "Key Contaminants and Target Values", there is no prescriptive lower limit for air changes per hour. Enough room airflow needs to be provided to achieve the performance-based target values defined in Table 1.
2) For rooms where there is not continuous monitoring and the capacity for an automatic response to changes in levels of contaminants, a reduction in air changes per hour to a minimum lower limit of 12 air changes per hour may be acceptable if the level of monitoring specified in Section 9.4.1, "Minimum Monitoring Requirements for Reducing Air Changes Per Hour", is conducted and monitored contaminant levels are within the target ranges specified in Section 9.3, "Key Contaminants and Target Values".
3) For rooms where the monitoring requirements noted in the previous two scenarios are not met, the recommended level of 15-20 air changes per hour applies. However, these facilities are encouraged to incorporate as much of the monitoring required for systems operating at less than 15-20 air changes per hour as possible, in order to gain a better understanding of the air quality of their rooms.

Monitoring room air quality must take into account the influence of room design and air distribution, so that monitors are positioned to ensure an accurate assessment of the air quality supplied to animals and humans. If at all possible, the monitoring devices should be positioned to directly monitor in the exhaust air duct from the room for best accuracy.

Sensors used for these measurements should be checked and calibrated approximately every six months or more frequently as needed to maintain sensor accuracy (see Section 9.4.4, "Sensor Calibration Requirements").

9.4.1 Minimum Monitoring Requirements for Reducing Air Changes per Hour

For facilities that are unable to continuously monitor air quality and respond automatically to any changes, the HVAC system may operate below 15-20 air changes per hour to a minimum of 12 air changes per hour if the following level of monitoring is implemented and there is a record of all activities (cage changing, research activities, etc.) and conditions (e.g., humidity) that could affect the air quality of the room. The time of year that monitoring takes place should be recognized as a factor, since humidity levels fluctuate annually and influence ammonia levels. The record of activity for the room should be correlated to the data from air quality monitoring, so that the source of any air quality problems can be investigated and appropriate action taken.

9.4.1.1 Initial Monitoring Period

The period of monitoring must encompass every activity that takes place in the room, and should cover each activity at least twice (e.g., two cage changes). The minimum time for the initial monitoring period is one month. In order to maintain an air change rate below 15-20 air changes per hour, recordings of contaminant levels must be consistently below the target levels specified in Section 9.3, "Key Contaminants and Target Values". If episodic increases above these levels are detected, the source must be investigated, the problem rectified, and the monitoring period extended.

If activities in a room fluctuate so much that all events cannot realistically be captured over a reasonable period of time, the air changes per hour should not be reduced. In other words, if room activities are highly variable, it may not be meaningful to monitor air quality with the goal of reducing the air change rate, and 15-20 air changes per hour should be maintained.

9.4.1.2 Follow-up Monitoring

Follow-up monitoring should occur every six months, with each monitoring period lasting for a period that covers all activities in the room at least once, with a two-week minimum period of monitoring.

9.4.2 Additional Considerations

There are potential risks associated with monitoring air quality intermittently instead of continuously. Favourable readings can lead to the conclusion that the air is consistently within the target values, but there may actually be periods between readings when these values are exceeded.

The type of research should be a consideration, and constant monitoring may be needed (or alternatively a high number of air changes per hour with verification that the source air is within the target value) for some research where consistent air quality is critical.

9.4.3 Sensor Accuracy Requirements

For both continual monitoring (every 15 minutes) and the periodic monitoring of Section 9.4.1, "Minimum Monitoring Requirements for Reducing Air Changes Per Hour", the sensors should meet the following accuracy and calibration requirements.

9.4.3.1 Ammonia

If a dedicated ammonia sensor is used, the following specifications apply. If a photoionization detector type of total volatile organic compounds sensor is used to detect ammonia, then the specifications in Section 9.4.3.3, "Particulates", for the photoionization detector type total volatile organic compounds sensor apply.

- Accuracy: ± 2 ppm or 2.5% of reading (whichever is greater)
- Resolution: 0.25 ppm

9.4.3.2 Carbon Dioxide

- Accuracy: ± 75 ppm up to 1000 ppm
- Resolution: 3 ppm
- Repeatability: 10 ppm

9.4.3.3 Particulates

A laser-based optical particle counter should be used for this application with a range or channel of 0.3 to 2.5 µm (PM 2.5) with the following minimum specifications:

- Accuracy: ± 25% of reading
- Resolution: <353,000 particles/m^3 (10,000 particles/ft^3)
- Concentration Range: >176,500,000 particles/m^3 (5,000,000 particles/ft^3)

9.4.3.4 Total Volatile Organic Compounds

A photoionization detector type total volatile organic compounds sensor with a 10.6 eV lamp should be used for this application with the following minimum specifications:

- Accuracy: ± 0.2 ppm (as isobutylene) or 2.5% of reading (whichever is greater)
- Resolution: 0.025 ppm
- Drift Stability: ± 2 ppm/6 months @ 5 ppm

9.4.4 Sensor Calibration Requirements

Whether spaces in laboratory animal facilities are being monitored on a permanent, installed basis, or periodically on a temporary basis for two to four weeks or more, high accuracy and stability of measurement are needed due to the differential measurements that are required for this application. As noted above, measurements need to be taken of both the supply air feeding the room as well as the room air or exhaust air leaving the room to determine the generation and impact on air quality of contaminant sources in the room. The types of sensors used for this application have readings that will drift over time for various reasons. Laboratory animal facilities in particular, due to the potential presence of ammonia, particles, hair, organic material, and other contaminants generated by the animals, can quickly foul air quality sensors and are especially challenging to the accurate use of sensors. Therefore, to ensure accurate and meaningful results, a frequent calibration regimen must be followed that is appropriate to the selected method of utilizing the sensors. Two recommended approaches are provided below.

The best approach to provide high accuracy and stability of these differential measurements is to use the same sensor for both supply and room or exhaust air measurements via an air sampling approach, so that normal offset drift of the sensor is cancelled out. If this air sampling or centralized sensor approach is followed, calibration is still needed since sensors can have other types of drift, but the frequency can be significantly reduced. A full factory or certified calibration every six months is appropriate for this method.

An alternative approach can also be followed that uses individual or separate sensors for the measurement of the supply air feeding a room as well as the room or exhaust air itself. When this approach is followed, calibration becomes much more critical since sensor drift is not being canceled out through an inherent differential measurement approach. Each sensor can drift up or down so large signal errors can quickly appear from using the supply reference and room or exhaust air sensors. To keep the measurements accurate, the sensors must be calibrated more frequently as a practical means to eliminate the errors from sensor drift. As a result, facilities that use this approach of individual, separate sensors should follow the standard scientific approach of doing a full factory or certified sensor calibration before every new set of measurements. In other words, for this application, sensors that are being used for the two-week follow-up monitoring should be calibrated every two weeks at the beginning of every new monitoring session. For the four-week initial monitoring, the sensors would then be calibrated every four weeks at the start of each initial monitoring session. Note that in no situation should these individual or separate sensors be used for over one month without recalibrating the sensors. For facilities where a measurement time of over one month is required for either the initial or follow-up monitoring of a room or space, each sensor must be replaced by a new calibrated sensor after one month of use to maintain measurement accuracy.

10 SAFETY, SECURITY, AND REDUNDANCY

10.1 SAFETY EQUIPMENT

Guideline 65

All required safety equipment must be installed to meet all applicable safety regulations without compromising the functionality of the laboratory animal facility.

Equipment such as fire extinguishers, fire hoses, emergency exit signage, eyewash stations, handwashing sinks, and emergency showers should be strategically located so that they are not bumped by equipment being moved through the facility. Hoses may be mounted in wall recesses. Fire alarms should be mounted so they will not be set off accidentally. Light alarms may be acceptable in some locations but must meet local fire regulations (see Section 8.1, "Sound and Vibration"). Emergency showers and eyewash stations should be strategically located but positioned such that they do not impede normal traffic flow. Units are available that fold up or fit into wall recesses. The health and safety office should be consulted regarding the location and number of emergency showers and eyewash stations that are required.

Sprinkler systems must be installed in animal facilities. Sprinkler systems should be designed so that they are easy to sanitize and do not harbour vermin. Systems in which water only enters the pipes when a heat detection device is activated can avoid problems associated with the water becoming rusty and dirty and potentially contaminating the room if leaks occur or the system is activated.

10.2 SAFETY OF PERSONNEL

Many tasks in animal facilities can be physically demanding, expose personnel to allergens, or create the potential for work-related injury. Common examples include:

- lifting and moving cases of water bottles, particularly after they have been filled
- handling and moving bags of food, bedding, or soiled bedding
- distributing clean cage racks and cages, and collecting soiled equipment for delivery to the dirty equipment staging
- emptying the soiled contents of each cage prior to washing
- distributing bedding into clean cages, manual or machine-assisted
- repeated bending or stooping to access cages on the lower shelves of cage racks and stretching or using step-up devices to access higher shelves on cage racks

A risk evaluation of the situations that personnel will be exposed to should be conducted to determine suitable equipment for mitigating risks (e.g., allergy, bacteriological agent, chemical, or physical).

The following equipment is available to help address many of these physical challenges:

- automatic watering systems to replace the use of water bottles (depending on the suitability for the animals and situation)
- hand-operated, electrically powered hydraulic dollies for movement of food and bedding
- electrically powered towing units for rack and cage movement
- vacuum systems for removing soiled bedding from dirty cages (without the need to scrape or bang them) and for the bulk collection of this material in containers for subsequent removal by motor vehicle
- robotic systems that pick up and knock out soiled bedding from cages prior to loading them on the tunnel washer belt
- robotic systems integrated with tunnel cage washers that collect and stack clean cages
- safe, ergonomically designed mobile platforms and stools for sitting to facilitate work with higher and lower rodent cages

10.3 SECURITY SYSTEM

Guideline 66

Security systems that limit access to authorized individuals only must be in place.

The security system is an essential component of the overall security plan for the laboratory animal facility. Each access point should have two control points that people have to pass through to provide a second deterrent for intruders.

Options for entry systems include lock systems that do not allow duplication of keys, card, or proximity badge access systems; keypads; and systems based on unique anatomical characteristics of individuals (e.g., thumbprint or retinal conformation). Card or proximity badge access systems have advantages over keys and keypads in that they provide monitoring of the passage of people, can restrict the times of access, can be deleted from the system if lost or stolen, and can be read under a protective garment and therefore reduce fomite concerns. A card or proximity badge access system is useful at the major entry points to a facility and in highly restricted areas, whereas keypads may be appropriate in less secure areas, such as animal rooms. A combination of keypads and card access can be used to increase security, especially against lost cards. An anti-passback system also adds an increased level of security.

10.4 REDUNDANCY

Guideline 67

Facilities must be designed with sufficient redundancy to provide critical functions and services, including adequate air changes and maintenance of differential pressures, during mechanical breakdowns and power outages.

It is important that facilities are designed to ensure the continued provision of critical functions and services, such as electrical supply, HVAC system, plumbing system (e.g., cage washer, autoclave, heating system, humidifier), compressed air for the autoclave and cage washers, the water source, elevators, computerized systems, and pumps.

Clean air at the appropriate temperature must be available 24 hours per day, year-round. In order to contain a biohazardous risk and protect the animals from contamination, pressure differentials should be maintained, and must be maintained in inclusion or exclusion situations.

Critical areas should be identified, and functions within the facility should be prioritized, along with load shedding strategies in the event of a power loss, to ensure the limited capacity of the emergency power system is directed to areas of highest priority (e.g., animal rooms, barrier rooms, and biohazard rooms would be a high priority, while the cage washer would be a low priority).

HVAC systems must be built with appropriate controls and monitoring systems. There should be separate fuses for normal, safety, and emergency power, and large facilities should have two independent power shafts to provide redundancy.

The animal facility should be divided into functional areas, with separate HVAC systems designed for each. For example, separate HVAC systems could supply the animal rooms, the surgical suite, personnel areas, and each biocontainment area.

There should be more than one supply and exhaust fan to each functional area, with the possible exception of areas for human occupancy. The total maximum capacity required for each area, including redundancy calculations, may be divided by the number of supply and exhaust fans to be installed. Normally, fans should be used at 50% of their total capacity, with the anticipation that outage times will be less than 12 hours. If two complementary fans are to be installed, each should be capable of supplying 100% of the total required capacity during an outage of the other fan. The supply and exhaust fans should also be sized and controlled so that differential pressures between critical areas are maintained during the failure of a fan. In containment facilities, an exhaust fan must be functional and capable of maintaining the containment facility at a negative differential pressure at all times (Government of Canada, 2022).

Backup chillers and heat exchangers should be installed. These should be individually sized to meet the maximum requirements independently, and then run at 50% capacity. This will allow one unit to meet all requirements while the other is being repaired or serviced. An example of a dual parallel HVAC system is given in Diagram 22.

Generator capacity should be available to operate the animal facility at normal levels during grid failures. If this is not possible, power must at least be available to maintain the HVAC system, emergency lighting, and other critical equipment, such as surgical lights, life monitors, ventilated racks (particularly for sealed cages), and the building automation system, to ensure the welfare of the animals is not compromised.

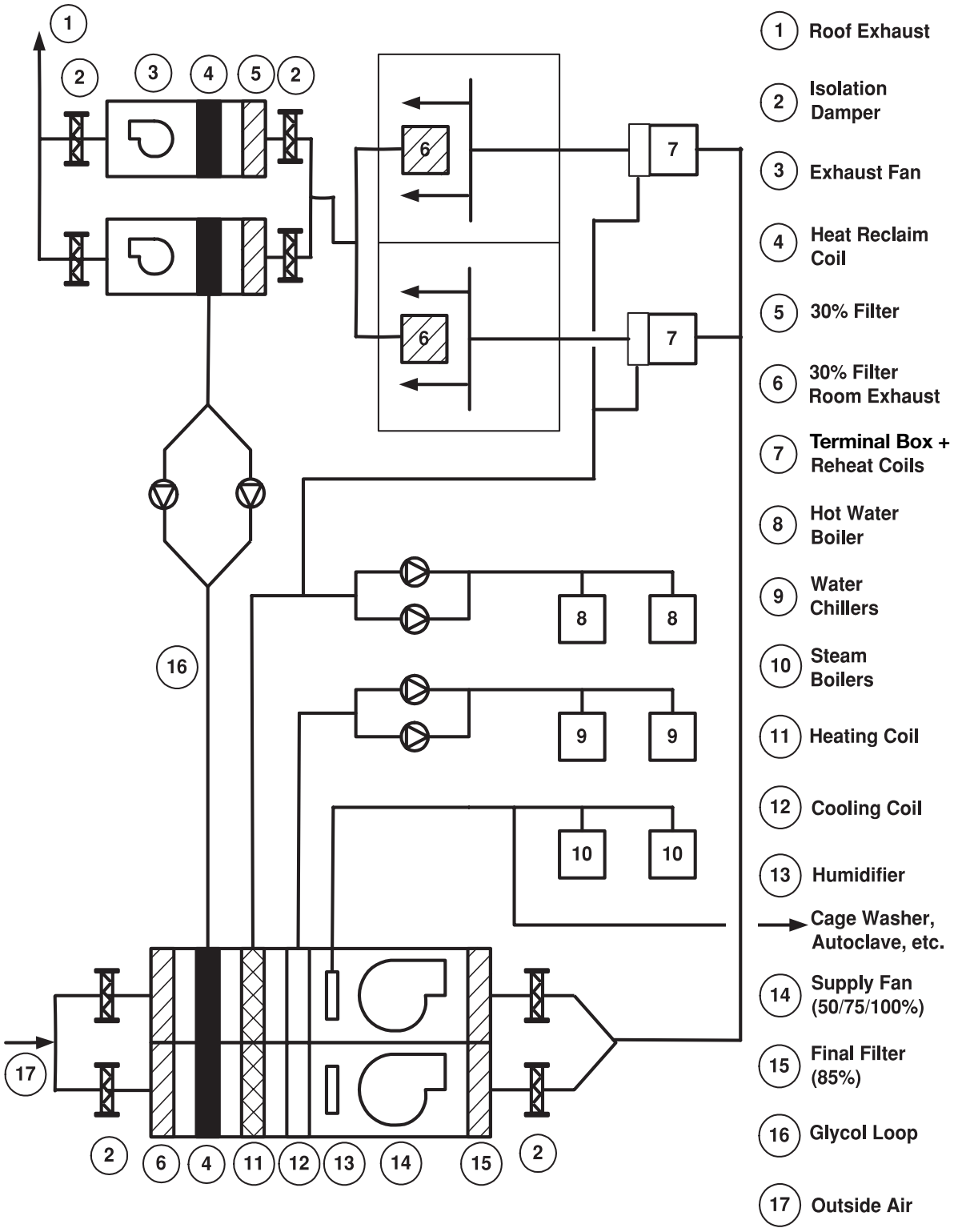


Diagram 22 Dual HVAC system

REFERENCES

More information about documents marked "in prep." can be found in the Guidelines section of the CCAC website.

Al Horr Y., Arif M., Kaushik A., Mazroei A., Katafygiotou M. and Elsarrag E. (2016) Occupant productivity and office indoor environment quality: A review of the literature. *Building and Environment* 105:369-389.

American Conference of Governmental Industrial Hygienists – ACGIH (2000) *Guide to Occupational Exposure Values*. Cincinnati OH: ACGIH.

American Society of Heating, Refrigerating and Air-Conditioning Engineers – ASHRAE (2016) *Standard 62.1-2016 – Ventilation for Acceptable Indoor Air Quality*. Atlanta GA: ASHRAE.

Bellhorn R.W. (1980) Lighting in the animal environment. *Laboratory Animal Science* 30(2):440-450.

Brainard G.C., Hanifin J.P., Barker F.M., Sanford B. and Stetson M.H. (2001) Influence of near-ultraviolet radiation on reproductive and immunological development in juvenile male Siberian hamsters. *The Journal of Experimental Biology* 204:2535-2541.

Brydges N. and Braithwaite V.A. (2008) Measuring animal welfare: What can cognition contribute? *Annual Review of Biomedical Sciences* 10:T91-T103.

Canadian Association for Laboratory Animal Medicine – CALAM (2020) *CALAM Standards of Veterinary Care*. Toronto ON: CALAM.

Canadian Council on Animal Care – CCAC (2005) *CCAC guidelines on: the care and use of fish in research, teaching and testing.* Ottawa ON: CCAC (accessed on 2024-07-16).

Canadian Council on Animal Care – CCAC (2009) *CCAC guidelines on: the care and use of farm animals in research, teaching and testing.* Ottawa ON: CCAC (accessed on 2024-07-16).

Canadian Council on Animal Care – CCAC (2020) *CCAC guidelines: Zebrafish and other small, warm-water laboratory fish.* Ottawa ON: CCAC (accessed on 2024-07-16).

Canadian Council on Animal Care – CCAC (2021) *CCAC guidelines: Animal welfare assessment*. Ottawa ON: CCAC (accessed on 2024-07-16).

Canadian Council on Animal Care – CCAC (2023) *CCAC guidelines: Wildlife*. Ottawa ON: CCAC (accessed on 2024-07-16).

Clough G. and Fasham J.A.L. (1975) A "silent" fire alarm. *Laboratory Animals* 9(2):193-196.

Dauchy R.T., Wren M.A., Dauchy E.M., Hanifin J.P., Jablonski M.R., Warfield B., Brainard G.C., Hill S.M., Mao L., Ooms T.G., Dupepe L.M. and Blask D.E. (2013) Effects of spectral transmittance through red-tinted cages on circadian metabolism and physiology in nude rats. *Journal of the American Association for Laboratory Animal Science* 52:745-755.

Dauchy R.T., Wren-Dail M.A., Hoffman A.E., Hanifin J.P., Warfield B., Brainard G.C., Hill S.M., Belancio V.P., Dauchy E.M. and Blask D.E. (2016) Effects of daytime exposure to light from blue-enriched light-emitting diodes on the nighttime melatonin amplitude and circadian regulation of rodent metabolism and physiology. *Comparative Medicine* 66(5):373-383.

Dawkins M.S. (2008) The science of animal suffering. *Ethology* 114(10):937-945.

Deutsche Forschungsgemeinschaft (2012) *List of MAK and BAT Values 2012*. Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, Report No. 48. Germany: Wiley-VCH.

De Vera Mudry M.C., Kronenberg S., Komatsu S. and Aguirre G.D. (2013) Blinded by the light: retinal phototoxicity in the context of safety studies. *Toxicologic Pathology* 41(6):813-825.

Duncan I.J.H. (2006) The changing concept of animal sentience. *Applied Animal Behaviour Science* 100(1-2):11-19.

Ferrecchia C.E., Jensen K. and Van Andel R. (2014) Intracage ammonia levels in static and individually ventilated cages housing C57BL/6 mice on 4 bedding substrates. *Journal of the American Association for Laboratory Animal Science* 53(2):146-151.

Fidler I.J. (1977) Depression of macrophages in mice drinking hyperchlorinated water. *Nature* 270(5639):735-736.

Gamble M.R. and Clough G. (1976) Ammonia build-up in animal boxes and its effect on rat tracheal epithelium. *Laboratory Animals* 10(2):93-104.

Government of Canada (n.d.) *Canadian Drinking Water Guidelines* [Web page]. Government of Canada (accessed on 2024-07-16).

Government of Canada (2016a) *Canadian Biosafety Handbook,* 2nd Edition. Ottawa ON: Government of Canada.

Government of Canada (2022) *Canadian Biosafety Standard*, 3rd Edition. Ottawa ON: Government of Canada.

Government of Canada (2023) *Transportation of Dangerous Goods Regulations* [Web page]. Minister of Justice (accessed on 2024-07-16).

Government of the Hong Kong Special Administrative Region, Indoor Air Quality Management Group (2003) *A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places*. Hong Kong: Hong Kong Special Administrative Region Government.

Hall J.E., White W.J. and Lang C.M. (1980) Acidification of drinking water: Its effects on selected biologic phenomena in male mice. *Laboratory Animal Science* 30(4 Pt 1):643-651.

Harrison D.J. (2001) Controlling exposure to laboratory animal allergens. *Institute for Laboratory Animal Research Journal* 42(1):17-36.

Health Canada – HC (1995) *Indoor Air Quality in Office Buildings: A Technical Guide*. Ottawa ON: Health Canada.

Heeke D.S., White M.P., Mele G.D., Hanifin J.P., Brainard G.C., Rollag M.D., Winget C.M. and Holley D.C. (1999) Light-emitting diodes and cool white fluorescent light similarly suppress pineal gland melatonin and maintain retinal function and morphology in the rat. *Laboratory Animal Science* 49(3):297-304.

Hermann L.M., White W.J. and Lang C.M. (1982) Prolonged exposure to acid, chlorine, or tetracycline in drinking water: Effects on delayed-type hypersensitivity, hemagglutination titers, and reticuloendothelial clearance rates in mice. *Laboratory Animal Science* 32(6):603-608.

Illuminating Engineering Society of North America (IES) – (n.d.) *IES Website* [Web page]. IES (accessed on 2024-07-16).

McLeod V. (2011) Breathing easy: Keeping tabs on indoor air quality. *Animal Lab News.*

Mendl M., Burman O.H.P., Parker R.M.A. and Paul E.S. (2009) Cognitive bias as an indicator of animal emotion and welfare: Emerging evidence and underlying mechanisms. *Applied Animal Behaviour Science* 118(1-3):161-181.

National Institutes of Health – NIH (2019) *Design Requirements Manual*. Bethesda MD: NIH. *Contemporary Topics in Laboratory Animal Science* 34:93-98.

Sharp G.P. (2010) Demand-based control of lab air change rates. *ASHRAE Journal*. February 2010:30-41.

Smyth H.F. Jr (1956) Improved communication – hygienic standards for daily inhalation. *American Industrial Hygiene Association Journal* 17(2):129-185.

Sørensen D.B. (2014) Shedding ultraviolet light on welfare in laboratory rodents: Suggestions for further research and refinement. *Animal Welfare* 23(3):259-261.

Swanson M.C., Campbell A.R., O'Hollaren M.T. and Reed C.E. (1990) Role of ventilation, air filtration and allergen production rate in determining concentrations of rat allergens in the air of animal quarters. *American Review of Respiratory Diseases* 141(6):1578-1581.

United States Department of Labor (n.d.-a) *Chemical Sampling Information – Ammonia* [Web page] (accessed on 2024-07-16).

United States Department of Labor (n.d.-b) *Chemical Sampling Information – Carbon Dioxide* [Web page] (accessed on 2024-07-16).

United States Environmental Protection Agency – US EPA (n.d.) *Reviewing National Ambient Air Quality Standard (NAAQS): Scientific and Technical Information* [Web page] US EPA (accessed on 2024-07-16).

United States Green Building Council – USGBC (2007) Indoor Environmental Quality In: *LEED v2.2 New Construction Reference Guide*. Washington DC: USGBC.

Washington State Department of Health (2003) *School Indoor Air Quality Best Management Practices Manual*. Office of Environmental Health and Safety Indoor Air Quality Program.

Wolfle T.L. and Bush R.K. (2001) The science and pervasiveness of laboratory animal allergy. *Institute for Laboratory Animal Research Journal* 42(1):1-3.

WorkSafeBC (n.d.) *Table of exposure limits for chemical and biological substances* [Web page]. In: Occupational Health and Safety (OHS) Regulation, Guidelines Part 5, Chemical Agents and Biological Agents (accessed on 2024-07-16) .

APPENDIX 1
EXAMPLES OF DETAILED SPACE DESCRIPTIONS

EXAMPLE 1 OF ANIMAL ROOMS

No. Required: 25

I.D. No.: M-1

Space Name: Conventional animal room

Location: Medical sciences building at a large university

Size/Configuration: 9.29 m^2 (10' x 10'; or 100 ft^2)

Purpose: Holding small animals. Depending upon the exact size and obstructions (columns, etc.), it will hold between two and four small animal racks. Not intended for large animals.

Chemicals/Pathogens: Conventional

Relationships: Access from conventional corridor with unidirectional traffic flow from restricted access corridor to general access corridor.

ARCHITECTURAL	Floors	• Seamless epoxy with integral cove base
	Walls	• Epoxy paint on concrete block
	Ceilings	• Epoxy paint on drywall
	Doors	• 112 cm x 213 cm (44" x 84") • Hollow metal with view light • Hollow metal frames grouted solid
	Hardware	• Push, pull, closer, armour plate, weatherstrip, door bottom, hold open, deadbolt
	Cabinetry	• 76 cm (30") stainless-steel shelf above the sink
MECHANICAL	HVAC	• 15 air changes per hour • Temperature 18°C to 26°C, ± 1°C of setpoint • 50% relative humidity, ± 5% • Use 30% filters in lieu of exhaust grilles
	Plumbing	• Stainless-steel handwash sink with wrist blades

ELECTRICAL	Lighting	• 650 lux (60-foot candles) recessed vapour-proof fluorescent with smooth lenses, double-switched • Half lamps to timed wall switch, half lamps to central lighting control computer • 1085 lux (100-foot candles) at sink, on timed wall switch • Three weatherproof GFI duplex outlets on circuit dedicated to room plus one 20-amp outlet on dedicated circuit
	Communications	
EQUIPMENT	Fixed	
	Moveable	• Occasional laminar flow rack
	Miscellaneous	• Vacuum hose connection to corridor, vacuum hose hook, mop, hooks, paper towel dispenser

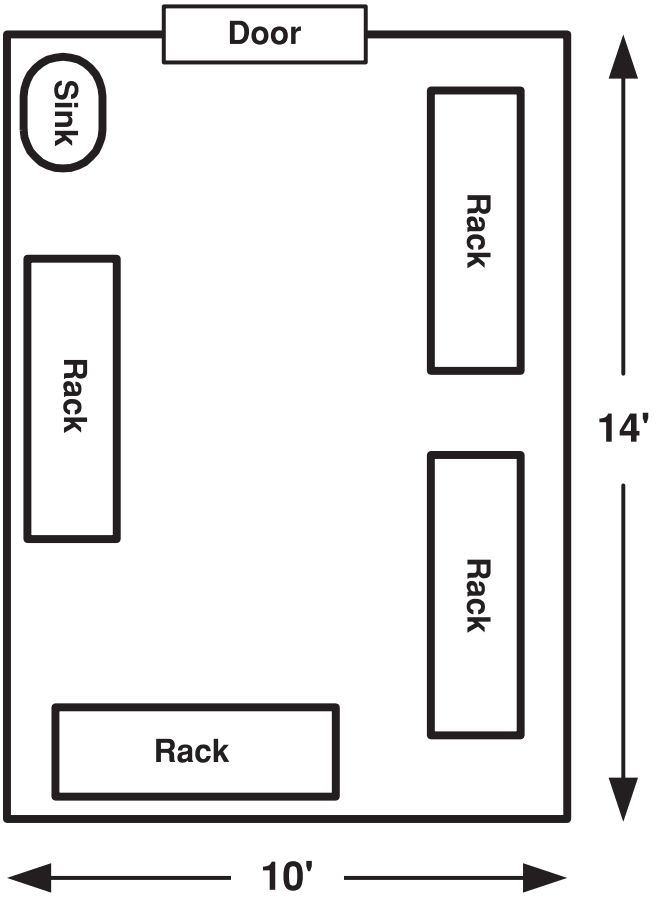


Diagram 1 Conventional animal room

EXAMPLE 2 OF ANIMAL ROOMS

No. Required: 10

I.D. No.: M-3

Space Name: Cubicle room

Location: Medical sciences building at a large university

Size/Configuration: 31.6 m^2 (340 ft^2) with 7 alcoves with full glass aluminum doors and frames

Purpose: Provide individual housing for one rack per alcove without tying up an entire room.

Chemicals/Pathogens: Conventional

Relationships: On general access corridor and west-end mono-directional corridors.

ARCHITECTURAL	Floors	• Seamless epoxy with integral cove base
	Walls	• Epoxy paint on concrete block
	Ceilings	• Epoxy paint on drywall
	Doors	• 112 cm x 213 cm (44" x 84") • Hollow metal with view light • Hollow metal frames grouted solid • To cubicles: pair of aluminum doors
	Hardware	• To room: push, pull, closer, armour plate, weatherstrip, door, bottom, hold open, deadbolt • To cubicles: lock, pull, hold open, flush bolt (head only)
	Cabinetry	• Stainless-steel countertop with lockable wall cabinet above
MECHANICAL	HVAC	• 15 air changes per hour • Supply and exhaust in each cubicle • Temperature 18°C to 26°C, ± 1°C of setpoint • 50% relative humidity, ± 5% • Use 30% filters in lieu of exhaust grilles
	Plumbing	• Stainless-steel handwash sink with wrist blades

ELECTRICAL	Lighting	• 650 lux (60-foot candles) recessed vapour-proof fluorescent with smooth lenses, double-switched • Half lamps to timed wall switch, half lamps to central lighting control computer • 1085 lux (100-foot candles) at sink, on timed wall switch • One weatherproof GFI duplex outlet at 198 cm (6'6") above finished floor in each cubicle and at 107 cm (3'6") at counter • Dedicated circuit for room
	Communications	• Intercom
EQUIPMENT	Fixed	
	Moveable	
	Miscellaneous	• Vacuum hose connection to corridor, vacuum hose hook, mop • Hooks in every cubicle and in common area, paper towel dispenser

EXAMPLE OF A DATASHEET FOR A MORE COMPARTMENTALIZED SPACE

SPACE DATASHEET		
NAME OF INSTITUTION: **PROJECT NUMBER:** **IDENTITY OF SPACE:** **GENERAL LOCATION (ZONE OR SUITE):**		
ARCHITECTURAL CRITERIA	Function	
	Area required	
	Number of cages	
	Number and description of racks	
	Maximum personnel at any one time	
	Biosecurity status	
	Biosafety status	
	Required sound isolation (sound transmission coefficient)	
FUNCTIONAL ADJACENCIES	Primary	
	Secondary	
PHYSICAL ADJACENCIES		
MATERIALS AND FINISHES	Floors	
	Finish (e.g., non-slip)	
	Floor to wall junction (e.g., integral cove base)	
	Walls	
	Ceilings	
	Doors	
	Window or viewing ports	
	Frame	
	Jamb protection	
EQUIPMENT	Biosafety cabinet	
	Fume hood	
	Workstation	
	Other	

HVAC	Temperature setpoint	
	Relative humidity	
	Heating	
	Cooling	
	Directional airflow	
	Air changes per hour	
	Air exhaust	
	Air supply	
	Special room filtration	
	Special exhaust	
	Heat-generating equipment	
	Mechanical noise criteria	
	Other	
POWER RECEPTACLES	Special equipment	
	Emergency (quantity)	
	GFI (quantity)	
	Dedicated circuits (quantity)	
	Other	
LIGHTING	Light type	
	Light intensity	
	Special lighting	
	Other	
COMMUNICATIONS	Telephone (quantity)	
	Data (quantity)	
	Other	
PLUMBING	Cold water	
	Hot water	
	Purified water	
	Animal water	
	Vacuum	
	Oxygen	
	Natural gas	
	CO_2 gas	
	Other gases	
	Sinks	
	Cup sink	
	Eyewash	
	Safety shower	

	Floor drains	
	Hose bib	
	Mixing station	
	Other	
FIRE PROTECTION	Sprinkler system	
	Extinguisher	
	Fire alarm	
	Horn	
	Strobe	
	Other	
SECURITY/ MONITOR	Security access	
	Badge reader	
	Special monitoring	
HAZARDOUS STORAGE	Flammable	
	Chemical	
	Safety closet	
	Other	
COMMENTS:		

GLOSSARY

Air changes per hour (also known as air exchange per hour) – The number of times the volume of air in a room is supplied to and exhausted from the room in one hour.

Allergen – A substance that causes an allergic reaction.

Biological safety (or biosafety) cabinet – A primary containment device that provides protection for personnel, the environment, and the product (depending on biosafety cabinet class), when working with biological material.[1]

Clean air – Air that meets the supply air target values of 0 ppm ammonia, 350-600 ppm carbon dioxide, <28.2 million particulates (PM 2.5)/m^3, and 0 ppb total volatile organic compounds.

Cross-contamination – The unintentional transfer of contaminants from one location to another.

Dilution ventilation – The replacement of a portion of the contaminated air with clean air to reduce the concentration of contaminants.

Directional air flow – The movement of air from an area of high pressure to an area of low pressure (see also pressure gradients).

Diversity factor (also known as diverse air exchange rates) – The operation of different rooms at different ventilation rates within a facility, taking into account the air quality of the room and the required pressure differences with respect to adjacent rooms and corridors.

Episodic events – Situations that cannot be predicted and are not related to the use of good systemic and operational approaches and controls (e.g., human error, broken or failing equipment).

Particulates – Very small particles of a substance; in terms of monitoring air quality, particles less than 2.5 µm in aerodynamic diameter are of concern, as they can remain suspended in the air for a long time and may present health concerns.

Pressure gradients – Different air pressures that are maintained between rooms and corridors to control the movement of air and eliminate a potential source of cross-contamination; for more information, see Section 8.3.7, "Differential Pressure".

Thermal load – The amount of heat generated from all sources present such as equipment, lighting, animals, and people.

Total volatile organic compounds – A grouping of various organic compounds that are present in gaseous state.

1 From the *Canadian Biosafety Standard*, 3rd Edition (2022).