Phoenix Controls
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Ensuring
Environmental
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Vivarium Sourcebook

5th Edition

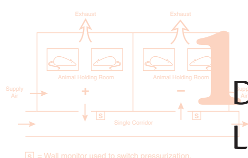
A Thorough Understanding of Laboratory Animal Environments

Laboratory animal facilities, also known as vivariums, require more detailed and focused design engineering than most other types of laboratory environments. The stability and quality of the animals' environment is vital to their well-being and to the integrity of research. In addition, the ventilation system must create a safe, comfortable working environment for caregivers. It must ensure that contaminated and odorous air is exhausted and that correct room pressurization is maintained.

Phoenix Controls has built its reputation on providing quality airflow controls for critical room environments and is recognized as the innovative leader in laboratory airflow controls. This sourcebook provides useful information for those involved with animal care facilities, including descriptions of airflow control approaches that satisfy the specialized needs of these environments. A compilation of pertinent standards and guidelines is also provided.

Phoenix Controls Corporation wishes to acknowledge the assistance of Jack Hessler, DVM and Barbara Johnston, DVM for their review of this document; and Frank Hoek for the cover photo of the cage rack.

Phoenix Controls Vivarium Sourcebook



A Brief History of Laboratory Animal Facilities

Before the 1950s, laboratory animal facilities were constructed almost exclusively as makeshift housing areas to accommodate animals for research. Modified horse barns with wooden or concrete floors were commonplace, as were wooden or wire mesh cages and glass jars. Ventilation of the animal rooms was often achieved through screened windows and doors and was enhanced by portable fans in the more elaborate facilities.

Recognizing a need to improve animal care in the biomedical industry, an Animal Care Panel, now known as the American Association for Laboratory Animal Science (AALAS), met in 1950 to discuss the direction of the industry and to establish guidelines. In 1963, the first edition of what is now the *Guide for the Care and Use of Laboratory Animals (the Guide)* was published and is now maintained by the Institute of Laboratory Animal Research (ILAR). This book has become the recommended standard for the design and operation of today's animal research programs. The Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC), an animal welfare organization, was established in 1965 to promote high standards of animal care and use. AAALAC uses the most recent revision of *the Guide* as its primary reference in evaluating programs at institutions that seek AAALAC accreditation.

This chapter presents an overview of laboratory animal facilities and the key elements basic to the design of airflow control systems for these environments.

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1 Design Issues for Laboratory Animal Facilities

Primary Objectives of Ventilation Systems

The airflow control system for a vivarium should be designed to achieve:

- A stable environment for animals
- Safety and comfort for animals and personnel

A Stable Environment for Animals

Minor changes in vivarium conditions can be devastating to scientific research. For this reason, the role of the airflow and climate control system in an animal facility cannot be overemphasized. The *Guide for the Care and Use of Laboratory Animals* states that "Proper housing and management of animal facilities are essential to animal well-being, to the quality of research data and teaching or testing programs in which animals are used, and to the health and safety of personnel (ILAR, p. 21)." A well-designed HVAC system will minimize variations in climatic conditions so that research results can be generated in a stable, trustworthy environment.

> "Environmental stability is of the utmost importance in minimizing behavioral and physiological changes which could confound experimental data."
>
> –*R.C. Simmonds, DVM,* Handbook of Facilities Planning, *pp.* 2-3

Safety and Comfort for Animals and Personnel

Biomedical researchers may state that the primary purpose of the ventilation system in a vivarium is to control the path of contaminants to provide safety for animals and personnel. Facilities engineers, on the other hand, may contend that conditioning the space for comfort is the ventilation system's primary purpose. The fact is that a ventilation system can assure the safety and comfort of all occupants in the facility.

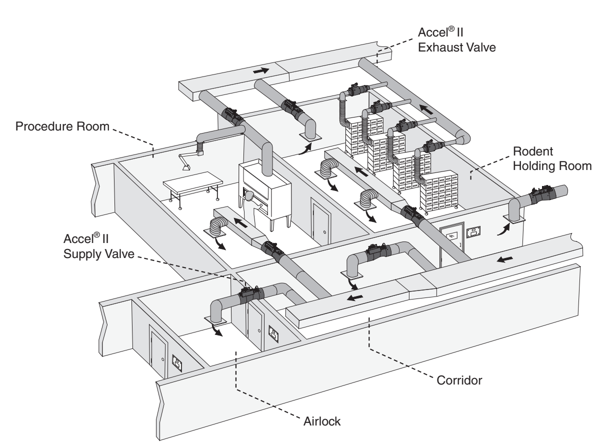


Figure 1-1. Vivarium ventilation requirements. *A reliable ventilation system is required to provide stability, safety and comfort.*

HVAC Systems and the Laboratory Animal Industry

Many laboratory animal facilities experience chronic heating, ventilating and air conditioning (HVAC) system problems that hinder the research from performing according to the owner's desires. It is only logical to consider ways to reduce or eliminate the sources of these problems so that research can be conducted without environmental disturbances.

The four most common problems related to HVAC systems for laboratory animal facilities are listed in the table below.

Problem	Typical Cause
Temperature and relative humidity instability	Inadequate airflow or temperature control
Room pressurization problems	Instability or incompatibility of devices
Lack of ventilation to accommodate more animals	Insufficient capacity or inefficient systems
High-maintenance airflow control devices	Rebalancing, recalibration, cleaning required

Resolving HVAC problems in laboratory animal facilities requires an understanding of how the facility is constructed, as well as the types of ventilation needed to ensure a stable, safe and comfortable environment. The remainder of this chapter provides an overview of the construction requirements for laboratory animal facilities, followed by a discussion of the unique ventilation control requirements in Chapter 2.

Room Types
(ILAR, pp. 72-73)

Space is required for:

- animal housing and care
- separation of species
- isolation of individual projects
- storage and receiving areas for food, bedding, pharmaceuticals, biologics, and supplies
- surgery and intensive care
- necropsy and radiography
- experimental, clinical, and diagnostic procedures
- containment facilities for use of hazardous biologic, physical, or chemical agents
- areas for washing and sterilizing equipment and supplies
- autoclaves for equipment, food, and bedding
- areas for holding soiled and clean equipment
- storage of wastes before incineration or removal
- cold storage or disposal of carcasses
- administrative office area
- staff training and education room(s)
- showers, sinks, lockers, toilets, and break areas

General Requirements for Laboratory Animal Facilities

The cost per square foot for an animal research facility is generally much higher than the typical laboratory space. For example, the total construction cost for typical lab buildings is from $230-290 per square foot, whereas a properly designed animal facility is in the range of $375-475 per square foot. The investment is greater for a vivarium due to the types of specialized material and construction required to withstand repeated abuse and heavy cleaning while maintaining continuous stability and precise control.

Room Construction

The materials and finishes used in a laboratory animal space are usually constructed to the standards used for a bio-safety level 2 building, even though the space may not conduct actual "BSL-2" procedures. According to the *Guide*, "Primary enclosures should be constructed with materials that balance the needs of the animal with the ability to provide for sanitation…They should be constructed of durable materials that resist corrosion and withstand rough handling without chipping, cracking, or rusting…Building materials should be selected to facilitate efficient and hygienic operation of animal facilities. Durable, moisture-proof, fire-resistant, seamless materials are most desirable for interior surfaces. Surfaces should be highly resistant to the effects of cleaning agents, scrubbing, high-pressure sprays, and impact (ILAR, pp. 23, 72)."

Although using materials with these characteristics greatly escalates construction costs, this has proven to be a wise choice when life cycle and research cost comparisons are considered.

Containment and Barrier Spaces

Containment and barrier spaces in animal research facilities are required when the control of contaminants is especially critical. These rooms are specifically designed to maintain a higher level of control of airborne infectious agents than in conventional animal rooms. These

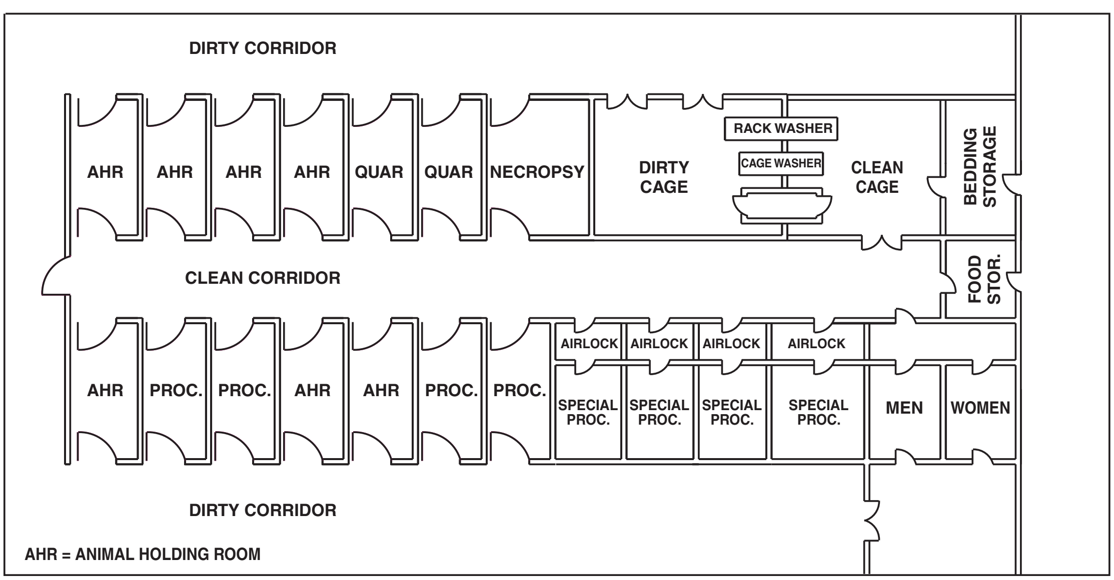


Figure 1-2. Dual-corridor vivarium design. *A vivarium includes many types of rooms due to the diversity of tasks and requirements unique to these facilities.*

applications require special design features and procedures for sterilization, decontamination and protection.

Type of Space	Description of Space
Conventional	Control of contaminants, but not as focused as barrier or containment
Containment	Contaminants must be contained
Barrier	Contaminants must be kept out, away from animals

Examples of contaminants: Bacterial, chemical, microbial and viral particles

All three types rely on specific barriers to achieve adequate control. In this context, *barrier* refers to a system, building feature or procedure to isolate clean and contaminated areas.

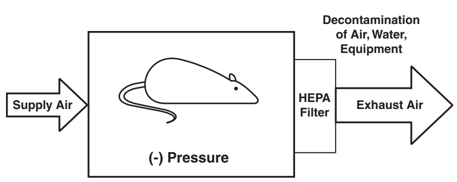
Examples of *containment devices* are:

- Filtered animal cages
- Biosafety cabinets/change stations
- Ventilated cage systems
- Fume hoods

Examples of *barriers* are:

- Access control systems and protocols
- Airlocks, ante rooms
- Exhaust air ventilation systems
- Taped-off or labeled areas
- Gates, walls, locked doors

Containment Room

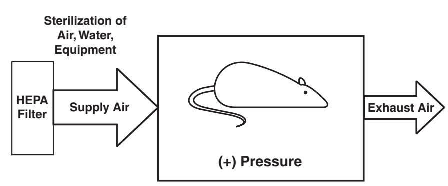


Keep contaminants IN
(Decontaminate after)

Decontamination of:

- Cages
- Bedding
- Waste products
- Water
- Garments worn by personnel

Barrier Room



Keep contaminants OUT
(Sterilize before)

Sterilization of:

- Cages
- Bedding
- Food
- Water
- Garments worn by personnel

2

This chapter discusses ventilation design requirements that ensure stability, safety and comfort in macro- and micro-environments.

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Ventilation Requirements for Laboratory Animal Facilities

Many species of animals are cared for and used in research facilities. Rodents, bats, ferrets, fish, frogs, non-human primates, pigeons, rabbits and sheep are among the types in use today. This chapter deals with ventilation design issues for general laboratory animal spaces, focusing on environments and airflow strategies for transgenic rodents. The purpose of this focus is the current high demand to house an increasing density of transgenic and knock-out rodents, typically mice. These animals have genes that have been altered or eliminated to make them particularly valuable in specific areas of biomedical research.

The Macroenvironment

The holding room is the macroenvironment. It requires a reliable monitoring and control system for temperature, relative humidity, airflow, and pressurization. The HVAC equipment requires redundancy and emergency power so that the animal's environment remains as constant and stable as possible.

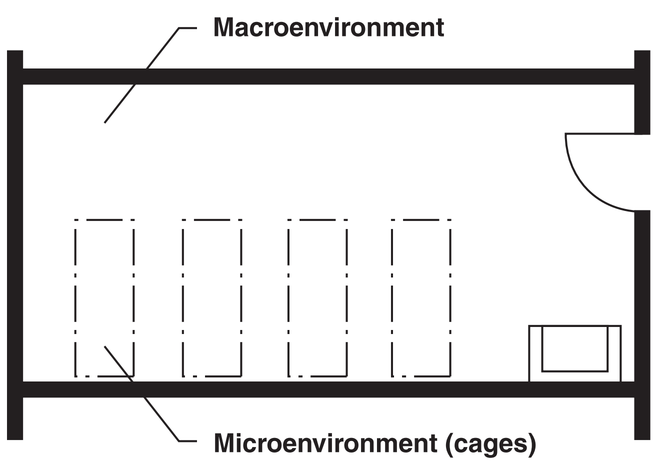


Figure 2-1. A macroenvironment. *The animal holding room is the secondary enclosure for transgenic rodents. Maintaining proper airflow, temperature, humidity, lighting and sound is critical for this environment.*

Various parameters must be controlled to meet the primary objectives for macroenvironments. The most important parameters are:

- Pressurization
- Temperature and relative humidity
- Ventilation rates

Pressurization

Pressurization zones are used in a vivarium to influence the path of airborne contagious agents and allergens. In general, barrier spaces are maintained at a positive pressure and containment areas are at a relative negative pressure.

For single corridor barrier facilities, a design that is widely used throughout the industry, there are several philosophies on the pressurization of holding rooms. (This does not refer to mixed facilities, where there are both "clean" and "dirty" rooms.) Some will maintain all holding rooms at a relative positive pressure to keep contaminants away from the disease-free animals. Others maintain all holding rooms at a relative negative pressure with the premise that all animals are disease-free. If a disease originates in an animal, the negative pressure will contain the disease in the room. The philosophy here is that negative pressure ensures that the disease will be contained from the time it is detected until it is eliminated. An evaluation of each facility will be necessary to determine the appropriate pressurization scheme based on the research, building layout and ventilation system capabilities. Switchable pressurization is a desirable feature for most facilities since it offers the most flexibility.

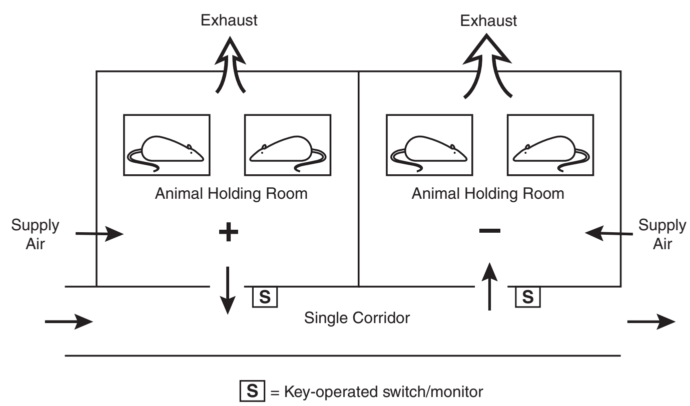


Figure 2-2. Holding room pressurization options. *The macro-environments may be maintained under positive pressure or negative pressure depending on the facility's needs. Some facilities require the room pressurization to be switchable.*

Negatively Pressurized Rooms	Positively Pressurized Rooms
• Quarantine rooms	• Surgery
• Holding areas for animals exposed to hazardous materials	• Housing of specific pathogen-free (SPF) animals
• Holding rooms for non-human primates	• Clean equipment storage

Source: Guide for the Care and Use of Laboratory Animals (ILAR, p. 76)

Important pressurization issues for lab animal facilities include:

- Architectural tightness and structural stability
- Differential pressurization control vs. volumetric offset
- Magnitude of pressurization

Architectural Tightness and Structural Stability

One of the most critical features of animal rooms is its architectural tightness, a fact proven when a room is commissioned. Meeting a desirable level of pressurization is extremely dependent on the construction of walls, ceilings, and doors, along with sealing the room envelope properly. Penetrations must be caulked adequately, and all doors must have durable, effective seals to prevent vermin entry and harborage (ILAR, p. 73) and control pressurization. The building's structural integrity also affects pressurization performance.

Differential Pressurization Control vs. Volumetric Offset

Volumetric offset is the most effective way to achieve stable pressurization in laboratory animal facilities. Differential pressurization control, the method of controlling to a specific pressure, has been more difficult and unstable. The American National Standards Institute (ANSI) and the American Industrial Hygiene Association (AIHA) support the use of volumetric offset over differential pressurization for laboratory environments: "Specifying quantitative pressure differential is a poor basis for design…What is really desired is an offset air volume (ANSI/AIHA Z9.5, section 4.11.4, p. 7)." The optimal solution may be volumetric offset control combined with a low-limit switch from an Active Pressure Monitor (APM).

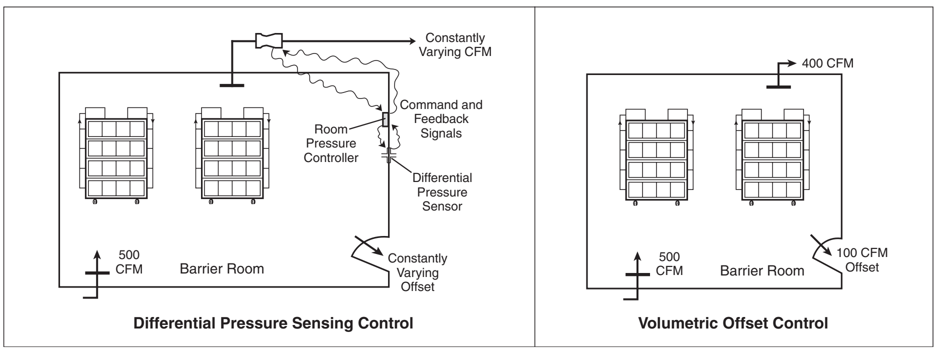


Figure 2-3. Volumetric offset recommended over pressurization control. *Accurate offset air volume control provides a stable animal and work environment.*

Magnitude of Pressurization

The magnitude of pressure differential between holding rooms and corridors varies in each facility. Most institutions use differential pressures ranging from 0.03 to 0.075 inches of water gauge (with 0.05 inch being the most common) and alarms when pressurization is lost. A pressure monitor for critical rooms helps indicate the level of pressurization.

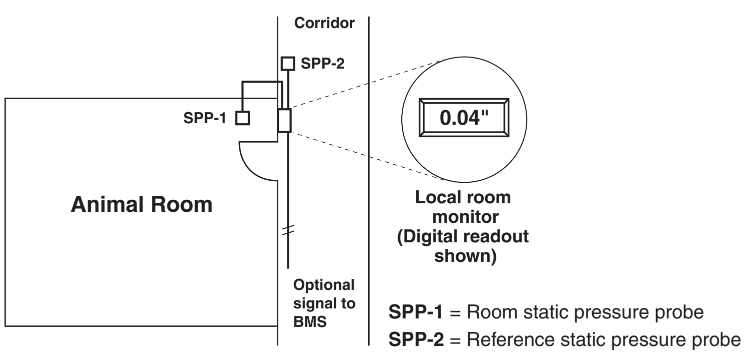


Figure 2-4. Room pressure monitoring. *Many facilities require room pressure monitoring. Options include local room monitoring and integration into the Building Management System.*

Ventilation Requirements

Laboratory animal facilities are notorious producers of odors and airborne allergens. The National Institute of Occupational Safety and Health (NIOSH) published an alert in 1999 (http://www.cdc.gov/niosh/animalrt.html) stating that more than half of laboratory animal personnel are affected by allergies, which prevents them from regularly performing investigative and husbandry tasks. Ventilation systems are cited as a primary means of eliminating or reducing the problem.

Temperature and Relative Humidity

A stable ventilation control system is required to properly maintain the environmental parameters of animal research facilities. Temperature is the most critical parameter and is usually controlled to ±2 °F or (±1 °C) with a set point in the range of 61-84 °F (16-29 °C) (ILAR, Table 2.4, p. 32). Each room in the facility requires its own temperature control system since there is a wide variety of heat loads from room to room. Facilities dedicated to a single species for a long duration may use a narrower design temperature range.

While the goal for relative humidity (RH) control is proposed to be 30-70% for most applications based on ILAR guidelines (p. 30), a typical set point should be around 50-55%. Serious consideration should be given to selecting any set point below 40%. The greater the distance from the equator in winter, the more difficult it may be to maintain RH above 30%. Because the range of acceptable RH is 30-70%, multiple rooms may be controlled as a single zone, especially if these are nonessential rooms, such as storage or certain types of procedure rooms. The use of trim devices for humidity control can be quite costly, so an evaluation should be done to determine if there is a justification for the expense.

Chapter 6, "Standards and Guidelines," lists recommended temperatures, relative humidity and heat generation data specific to particular species, and Chapter 4, "Control Applications," addresses temperature and humidity control systems.

Ventilation Rates

Animal research facilities use higher air change rates of 100% outside air than do other research laboratories. This is primarily due to the level of heat and contaminants generated in densely populated animal rooms. Although the *Guide* states that "10-15 fresh-air changes per hour…is considered an acceptable general standard (ILAR, p. 32)," rates of 18-20 changes per hour are not uncommon. Even with these elevated air change rates, excessive odors and airborne allergens may still be a problem, unless strategies are implemented to alleviate the problem. This topic is discussed in more detail later (see "The Microenvironment" section of this chapter).

Consideration of Lower Air Change Rates and Variable Air Volume Control

Lower air changes per hour (ACH) of 100% outside air have not been widely used in laboratory animal facilities, but there is merit in considering reductions. Variable air volume (VAV) control systems provide the greatest degree of flexibility and can allow for more efficient use of the ventilation system. The ability to reduce ventilation rates often justifies the additional investment for a VAV system.

"HVAC systems should be designed for energy conservation."–*ILAR, p. 75*

Facilities can consider reduced ACH when:

- The animal's primary enclosure (microenvironment) is not affected.
- Room conditions (T and RH) can be controlled with lower air change rates.
- Animal heat generation can be directly exhausted out of the room.
- The population of animals in a room decreases.
- Rooms are unoccupied by personnel.
- Procedures and functions are periodic (e.g., cage wash = 8 hours on, 16 hours off).

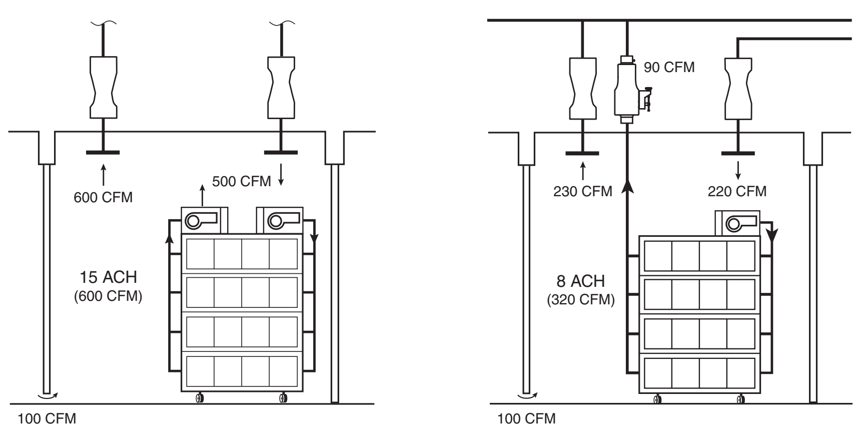
Each room requires a specific amount of ventilation to properly control the space. The use of more air than what is necessary to achieve the above is a waste of energy. A quality VAV system controls the room to the lowest proper ACH, responding to changes in the room so that the environment can remain stable and comfortable.

There are numerous benefits to using reduced air change rates, including:

- Energy conservation
- Lower operating and first costs
- Less noise and disruption from the HVAC system
- Less wear and tear on system components
- Increased housing capacity when ventilation is shifted from reduced ACH areas

Ventilated cage racks for rodents stabilize the animal's primary environment. If cage racks are connected to the building exhaust system, reduction of the room ACH is a logical consideration. By exhausting the rack air directly into the house exhaust system, odors, gaseous effluents and part of the cooling load are exhausted out of the room, rather than recirculated back to the room. The reduction in thermal and ventilation loads allows for more traditional air change rates of 6-8 ACH. VAV room control may also be considered to further enhance the room conditions and reduce energy consumption.

Variable air volume is discussed in greater detail in Chapter 4.



Lab A: 15 ACH
Cage air exhausted into the room

Lab B: 8 ACH
Cage air exhausted into building exhaust

Figure 2-5. Reducing air changes. *The cages in Lab A are exhausted into the room, requiring higher air changes (15 ACH) to remove heat, odors and gaseous contaminants. The cages in Lab B are exhausted into the building exhaust system, significantly reducing cooling loads, odors and volatile irritants in the room. This allows for reductions of air changes in Lab B.*

Ventilation Requirements

The Microenvironment

The cage is the animal's mircoenvironment, or primary surroundings. According to the *Guide*, primary enclosures should be designed to provide adequate ventilation...and not place stress on the animal's normal physiological and behavioral needs (ILAR, p.23).

Static, Filter-top Cages

One form of housing for rodents is filter-top cages, also known as *static* microenvironments, because air exchange is minimal (reportedly less than 1 ACH). The cages are kept on shelves or in ventilated enclosures. The filter-top is included on these cages primarily as a barrier to protect the animals from airborne pathogens, but can also serve as a containment space. Although filter-tops effectively limit the passage of airborne agents, the lack of flow causes cage humidity and gaseous concentrations to increase rapidly, requiring frequent bedding changes. Frequent bedding changes lead to costly labor, exposure to pathogens for both animals and personnel, additional wear and tear on the cages and the facility, and high utility costs. These disadvantages do not give cause to eliminate the use of this style of cage. In fact, the static cage is especially useful for Bio-safety Level 2 and 3 research, where containment is critical.

Figure 2-6. A static, filter-top cage for rodents. *Air exchange is minimal, usually around 1 ACH.*

Photo courtesy of Allentown Caging Equipment Co., Inc., Allentown, NJ

Ventilated Caging Systems

Since their introduction in the late 1970s, ventilated cage racks have become the desirable standard in rodent facilities, supplementing or reducing the use of static cages. Individual cages typically house 4-5 mice or 1-2 rats. Dedicated supply and exhaust fans with HEPA filters maintain positive (and sometimes negative) cage pressure and are usually mounted to the rack. Although the supply airflow on a 100+ cage rack is typically less than 50 CFM total, the ventilation rate in each cage is generally 50 air changes per hour or more. These high air changes reduce the concentration of ammonia and other waste products in the cages. Racks can also provide the support structure for auto-watering, a labor-saving system gaining acceptance at an increasing number of institutions today. All of these features contribute to an improved animal environment.

Rodent Holding Rooms

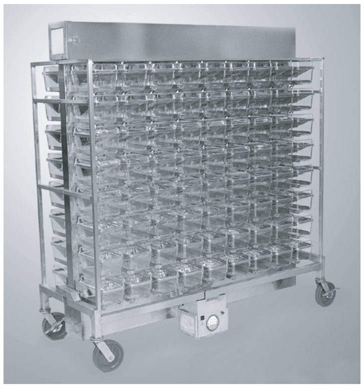


Photo courtesy of Alternative Design, Siloam Springs, AR

Photo courtesy of Lab Products, Inc., Seaford, DE

Photo courtesy of Allentown Caging Equipment Co., Allentown, NJ

Figure 2-7. Examples of ventilated cage racks for rodents.

Connecting Ventilated Cage Racks to Building Ventilation

Ventilated cage racks, as mentioned on the previous page, have grown in popularity in part because they allow for dramatically increased animal density in holding rooms. However, the rack fans deliver cage air back to the rooms and, when combined with the increased density, produce undesirable environmental issues, the most substantial of which is exposure to volatile irritants for workers in the holding rooms. The fans also produce noise, vibration, maintenance and cooling loads to the rooms. Two other deterrents to the use of rack fans are their costs and the difficulty of removing and cleaning them–tasks that are required periodically.

For these reasons, building designers have begun to incorporate methods for connecting racks to the building ventilation system that deliver clean, conditioned air to the cages and pull cage exhaust air out of the rooms.

Although this strategy may seem simple and logical, attempts to connect ventilated racks to the building systems have been problematic. Some have resulted in serious containment issues and environmental instability. Designing rack connections requires a thorough understanding of the ventilated rack flow control strategies and static pressure requirements to avoid these problems. Using pressure-dependent devices, such as manual dampers and blast gates, is one of the more common mistakes. These crude devices do not compensate automatically for pressure fluctuations in the duct system and, therefore, produce unstable flow control.

Phoenix Controls eveloped the *Cage Rack Valve*, a patented solution for controlling airflow in ventilated cage racks. This pressure-independent valve eliminates the ongoing balancing and flow control issues prevalent with these connections. See page 77 for more information.

Some Facts About Ventilated Cage Racks

1. The supply and exhaust flows for each rack must be at a constant volume and precisely stable.
2. The supply air to each rack must be HEPA filtered. Rack exhaust fans also include HEPA filters.
3. The supply airflow may be less than 50 CFM to the rack, but equates to over 50 ACH to the cage.
4. Each manufacturer of ventilated caging systems may differ from all others in its ventilation strategy for individual cages.
5. The more practical source of supply air for ventilated racks is the holding room, since the room air is typically close to the temperature and humidity levels desired for cages. The use of the building's central system gets very complicated and requires additional redundancy and environmental controls, resulting in a more expensive source of supply air.
6. The use of dampers, flow or pressure measuring devices has proven to be intensely frustrating and dissatisfactory. High-performance, pressure-independent flow controls are the best solution for connecting racks to the building system.

Ventilation Options for Rodent Holding Rooms

This section addresses four methods of ventilating cage racks, followed by a discussion of applications requiring multiple racks per valve and racks that require flows below the performance range [30-150 CFM (50-250 m^3/hr)] of the Phoenix Controls Cage Rack Valve. It is important to note that cage rack manufacturers continue to introduce new systems that may affect the ventilation strategies. Therefore, the integrated system requirements must be understood early so that appropriate solutions can be designed into projects before the cage racks arrive and system commissioning occurs.

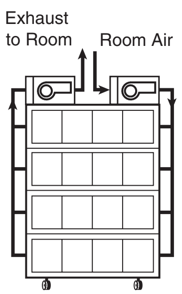


Figure 2-8. Room air with rack supply and exhaust fans (ventilation option #1).

Option #1: Room Air with Rack Supply and Exhaust Fans

Ventilated cage rack manufacturers provide both a supply and an exhaust fan/filter unit, each of which is removable for rack cleaning, relocation and fan/filter maintenance. The supply fan draws room air through HEPA filters to ventilate the cages with clean air. A 2-3 °F (1-2 °C) rise occurs across the fan. The rack exhaust fan also includes a HEPA filter since the blower pulls potentially contaminated air from the cages and must deliver clean air back into the room.

Advantages:

- The flow control method is simple.
- Rack configurations (placement of racks) in animal holding rooms are more flexible.
- HEPA filters reduce particle counts in the room.

Disadvantages:

- First and operating costs may be higher than Options #3 and 4.
  - Rack fans are costly, typically US $1500 or more per fan.
  - Fans generate heat, increasing room cooling requirements.
  - Fans exhaust animal heat to the room.
  - Rack fans (perhaps 8-18 per room) require maintenance.
  - Rooms require many wash-down duplex outlets, normally equipped with emergency power, to keep the racks ventilated.
- Noisy holding rooms. Each room usually includes 4-9 racks, requiring 8-18 fans. Since sound increases by 3dB every time a noise source doubles, the actual noise generated by rack fans in the room will be at least 9-12 dB louder than the sound from one fan.
- Vibration from fans. This is true even if isolators are included with the fans. Vibrations can be eliminated if the fans are mounted on shelves near the racks. This requires additional costs for the hardware and labor, and may add to the difficulty of room decontamination.
- Indoor Air Quality (IAQ) problems. Although HEPA filters can reduce particle counts in room air, gaseous effluent is exhausted into the room. These volatile irritants (odors, pheromones* and perhaps allergens) are very undesirable and should be eliminated to the greatest extent possible.
- Ergonomics. Removing fans from racks is cumbersome, especially when compared to Option #4.

* Pheromones are an animal's hormonal scent and can adversely affect the other animals in the room.

Option #2: Room Air with Rack Supply Fan, Exhaust Fan and Thimble

Similar to Option #1, the rack air is conveyed via the supply and exhaust fans with HEPA filters. In addition, the rack exhaust is ducted to the building exhaust system by a thimble or capture hood to decouple the rack fan and ductwork from the building exhaust system. Previous attempts to directly connect the rack exhaust to the building were very problematic because building duct pressure fluctuations created frequent imbalances in the flow, destabilizing the animal's environment.

Advantage:

- A properly designed and commissioned thimble application resolves pressure fluctuation problems. (Options #3 and 4 also solve these problems.)

Disadvantages:

- Most expensive first and operating costs.
  - This option includes the two rack fans at a cost of typically $1500 or more per fan, plus the costs of manifolded ductwork and difficult airflow balancing of pressure dependent devices (manual dampers or blast gates) at each rack drop.
  - Increased maintenance costs (over Options #3 and 4) since each rack has two fan and filter units.
  - Fans generate heat, increasing the room's cooling requirements.
  - Standard power and perhaps emergency power are required for each fan.
  - The manifolded thimble drops require future costly rebalancing.
- When the thimble's manual dampers/blast gates are mistakenly closed, rack exhaust will be delivered back to the holding room. This potentially causes an imbalance in rack ventilation and affects room pressurization, which affects containment in macroenvironments and microenvironments.
- Noise is still an issue since this method requires a rack exhaust fan, typically the noisier of the two rack fans.
- Unlike Options #3 and 4, exhaust fan vibration is still an issue, unless fans are mounted on a shelf in the holding room.
- This is the most cluttered option, due to the amount of hardware required:
  - Fan/filter units
  - Power cords
  - Flex connections
  - Thimbles
  - Blast gates or dampers
- If the airflow control device used for the manifolded duct serving the racks is not a high performance pressure independent valve, room pressurization can very likely be a problem area.

For these reasons, there is a trend away from the use of thimble connections.

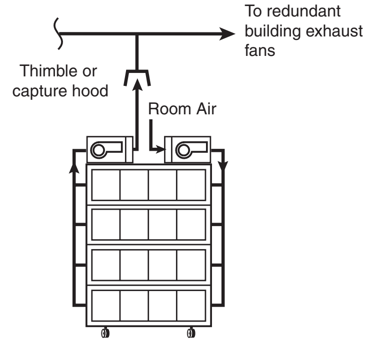
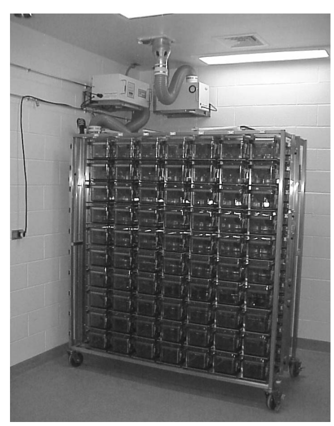


Figure 2-9. Room air with rack supply fan, exhaust fan and thimble (ventilation option #2).



Photos courtesy of Allentown Caging Equiment Company, Allentown, NJ

Ventilation Requirements

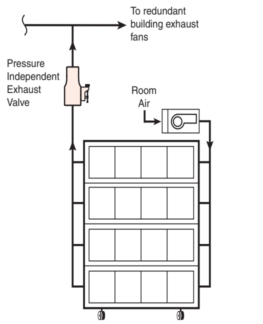
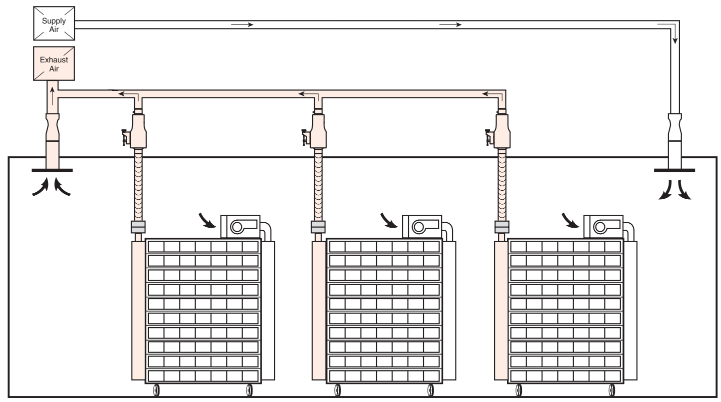


Figure 2-10. Room air with rack supply fan; rack exhaust connected directly to building (ventilation option #3).

Option #3: Room Air with Rack Supply Fan; Rack Exhaust Connected Directly to the Building

The exhaust side of ventilated racks is the more advantageous of the two sides to connect to the building ventilation system. This approach greatly improves the room's air quality, energy conservation and acoustics.



The constant volume Phoenix Controls Cage Rack Valve provides a simple and reliable method to make this connection directly, without the need for a thimble or exhaust fan/filter unit.

Advantages:

- Reliably removes animal heat, gaseous effluent, odors and allergens from the room.
- Maintains stability within the cages, even when exhaust duct pressure changes.
- Reduces first and operating costs, along with heat generation.
- Racks can be disconnected easily from the building system for cage changing or rack washing. (Vent racks are on wheels and are mobile, requiring occasional disconnection from the system.)
- Eliminates the need for electric power for the exhaust source since the fan/filter unit is no longer required. Electric cords and emergency power requirements are eliminated, reducing construction and operating costs.
- Simplified and more effective room decontamination process. The extent of the cage rack exhaust ventilation system is reduced to a single flex duct per rack. Eliminates the need to clean fans, filters, cords, dampers or thimbles in the room during the decontamination process.
- Improvements in macroenvironments and microenvironments. Noise and vibration from the fans are significantly reduced. Building fan noise is noticeably lower than rack fan noise.
- Maintenance costs are reduced since the valves do not have motors or other serviceable parts.

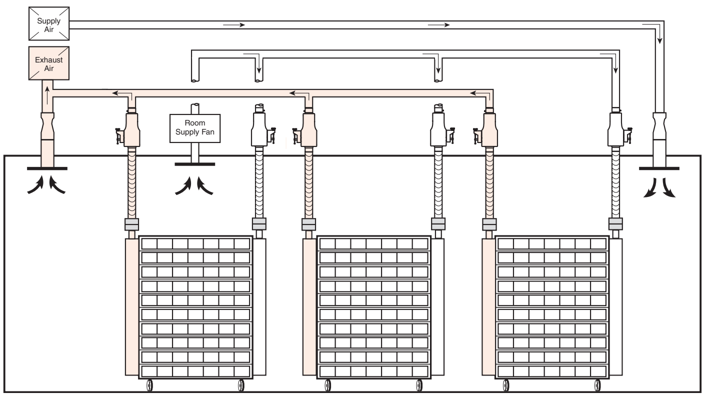
Disdvantages:

- Less flexibility with the room layout since racks must be placed near flex drops.
- Additional ductwork for exhaust.

Photo courtesy of Lab Products, Inc., Seaford, DE

Option #4: Directly Connect Rack Supply and Exhaust to Building Systems

Replacing both ventilated cage rack fans with stable connections to the building ventilation system can provide the greatest benefits, *if* the system is properly designed, installed and commissioned. The exhaust connections and benefits are the same as described for Option #3, only now the racks will also be free from the noise, vibration and additional heat source created by the rack supply fan, which potentially results in the lowest capital equipment and operating costs. This option also eliminates the need for a separate emergency power source for the cage rack fans and would rely instead on the building's HVAC system. According to the *Guide for the Care and Use of Laboratory Animals*, the HVAC system should already be designed to include emergency power (ILAR, p. 76).



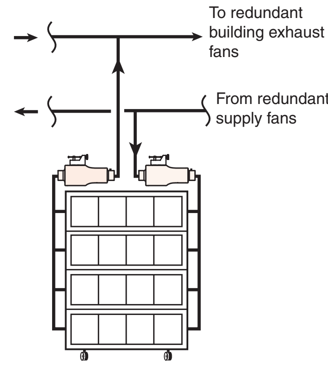


Figure 2-11. A rack supply and exhaust valve connected directly to the building system (ventilation option #4).

Advantages of Option #4 over Option #3:

- Clean animal holding rooms
  - Reduction in room hardware: rack fans, excess flex duct, power cords and wash-down duplex outlets are eliminated.
  - Simplified rack connection/disconnection: each rack has only two flex ducts with collars for quick connection.
  - Streamlined workflow: simplified decontamination procedures since fewer components/surfaces need to be cleaned.
- Quiet animal holding rooms
  - Very noticeable noise reduction: Fan noise is eliminated.
  - Noise sources are outside of space, plus low velocity airflow through racks and flex ensures low noise levels.

Disadvantages:

- Less flexibility with the room layout since racks must be placed near flex drops.
- Additional ductwork for exhaust and supply.
- If supply air to the racks is conditioned primary building air, the temperature and humidity control strategy can be complicated and very costly.

Pages 18-22 discuss two design methods for Option #4: the room supply fan and the dual supply air system.

Treatment of Rack Exhaust Air

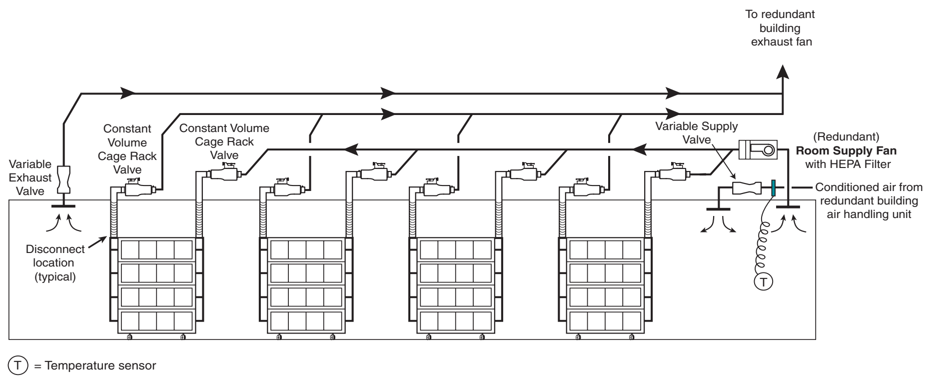
The air exhausted from ventilated cage racks carries particles from the cages into the exhaust chambers of the racks. These particles are mostly bedding dust, but can also be dander and hair. Some pass beyond the thin film filter in the individual cages. Viruses and other health hazards attach to particles.

Therefore, filtration of rack exhaust air is essential. The level of treatment ranges from coarse (30% efficient) filtration for typical applications to HEPA (high efficiency particulate air) filtration, when biohazards must be contained. Exhaust system components, such as turning vanes, sensing probes and fan blades, will accumulate dust, reducing the ventilation system's effectiveness and its capacity to maintain a safe and stable environment.

Option #4 with Room Supply Fan

Although it appears from Figure 2-12 that the supply air ducting makes this a recirculating system, it is the same flow schematic as the rack supply fan. Both fans draw conditioned room air across HEPA filters before delivering it to the cages. This is one of two methods used to provide supply air to the cages. For clarity, this method will be called the *room supply fan* method.

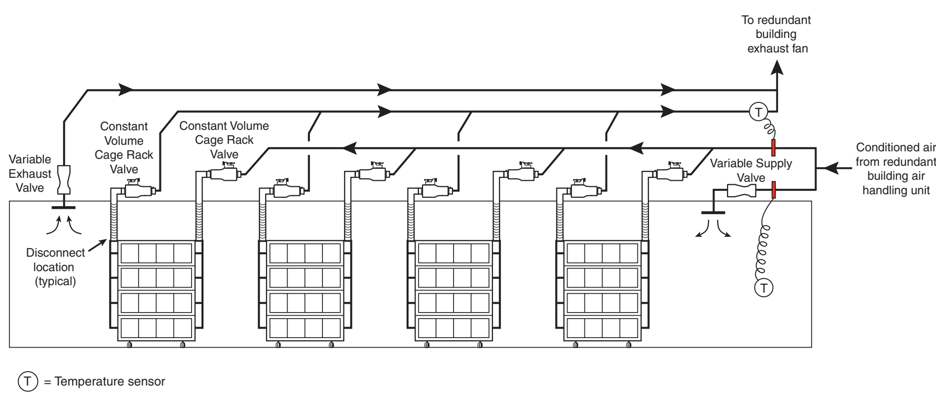
Figure 2-12. Option #4 with room supply fan.



Option #4 with Dual Supply Air System

The other method, called the *dual supply air system*, requires a more thorough evaluation of the control schemes for not just flow, but also for temperature, relative humidity and filtration. The dual supply air system splits the building primary air into two ducts: one duct and temperature control loop serve the room, and a separate duct and temperature control loop serve the cages. This control strategy is far more complicated and is discussed in greater detail on pages 19-22.

Figure 2-13. Option #4 with dual supply air system.



Statements made in favor of the *dual supply air system* are:

1. Room and cage environments are not the same. (This is true for both static and ventilated caging systems.)
2. Animals and people have different preferences in defining ideal environments.
3. Flexibility to control the environments differently is important.

Although these statements are valid, it is critical to consider a number of important issues in the design of such a system.

Critical Issues for Dual Supply Air Systems

Among the critical issues that must be addressed in the design and selection of a system that uses the dual supply air system are:

1. Effect of supply air temperature fluctuations on rodents
2. Cost of the additional (redundant) environmental control loop for the cages
3. Sensing for and controlling of the environmental control loop for the cages
4. Ability to sense and alarm high and low temperature limits properly
5. Distance of HEPA filters from the animals
6. Overcoming the additional static pressure from zone HEPA filters in a central system

Following is a discussion of each of these issues.

1. *Effect of supply air temperature fluctuations on rodents*

   Control of temperature and relative humidity, even with well-tuned building management systems, has been near or at the top of the list of problematic laboratory animal facility issues. This is especially true of manifolded systems, where multiple zones are served by a common air distribution and control system. Ducting the air directly to the racks removes the large buffer called the macroenvironment from these temperature fluctuations. NOTE: The reheat valves must fail closed in rodent holding rooms because the rodents can adapt more readily to 55 °F (13 °C) supply air, but cannot withstand temperatures that approach or exceed 90 °F (32 °C) for long periods. As one might imagine, disruptions to research and animal fatalities in these facilities are extremely costly, not just financially, but also with respect to time and to the progress in the area of biomedical science for which the research is being done.

2. *Cost of the additional (redundant) environmental control loop for the cages*

   The Guide for the Care and Use of Laboratory Animals discusses the importance of redundant HVAC systems for critical areas. If a vivarium director compiled a list of critical areas for environmental control in the animal facility, rodent holding rooms would be at or near the top of the list. Providing redundancy with a dual supply air system is extremely costly and may not fit in the already tight space (and budget) allocated for the rodent holding room infrastructure since it would include dual reheat coils and valves, dual humidifiers and dual temperature control loops with dual sensors. Drawing room air through a HEPA filter using a *room supply fan* is far simpler and much less expensive.

Most rodent holding rooms today are controlled to a room temperature of 70-73 °F (21-23 °C), which suits most personnel. And since the cage air for Options #1 and 2 is 2-5 °F (1-3 °C) warmer than the room air, the higher in-cage temperature is more suitable for the rodents. Edstrom Industries' Data Logger confirms this temperature rise to be true. When used in a ventilated cage that is occupied by five mice, the maximum number allowed, the in-cage temperature is typically around 2-5 °F warmer than the room when the rack is connected to the building exhaust system.

Drawing room air through a HEPA filter using a room supply fan is far simpler and much less expensive than using a dual supply air system.

3. *Sensing and controlling the cage's environmental control loop*

This is where it gets *extremely complicated*. As previously stated, most of today's ventilated racks provide clean, conditioned air to the cages and draw additional room air through the rack to create a negative pressure zone with respect to the room. The amount of air drawn from the room varies with the cage rack design or manufacturer and is typically 50-200% of the cage air flow.

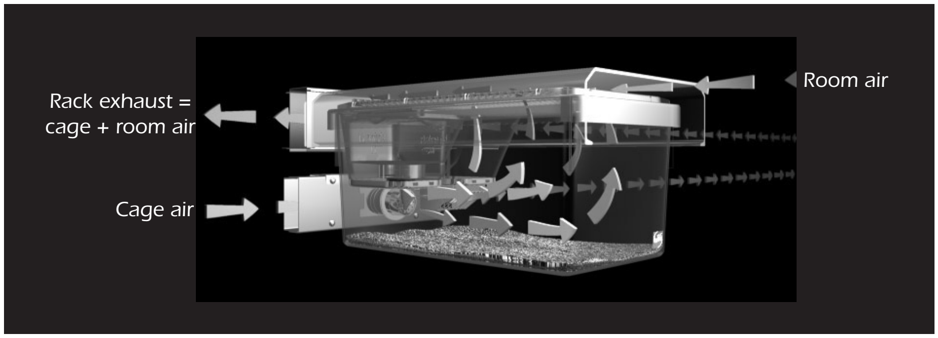


Image courtesy of Lab Products, Inc., Seaford, DE

Figure 2-14. Example of flow pattern through one type of ventilated cage. *Airflow patterns of a ventilated cage maintain a healthy, stable environment for the animals.*

Based on this fact, *where should the air temperature be sensed to control the supply air temperature to the cage racks on a dual supply air system?* Racks typically have 60-140 cages, each of which could be unoccupied or house as many as 5 mice or 2 rats. Not only would sensing temperatures in occupied cages be difficult and costly for temperature control, it would be very complicated, and as of today is not readily available or affordable. Also, using only one cage to sense temperature and relative humidity does not accurately represent the aggregate environment of all cages controlled on the supply duct.

Drawing room air into the cages through a HEPA filter with a room supply fan is far simpler and more stable. It relies on the room temperature being controlled to a set point that is 2-3 °F (1-2 °C) cooler than the desired cage entering air temperature. Most personnel are comfortable working in that environment.

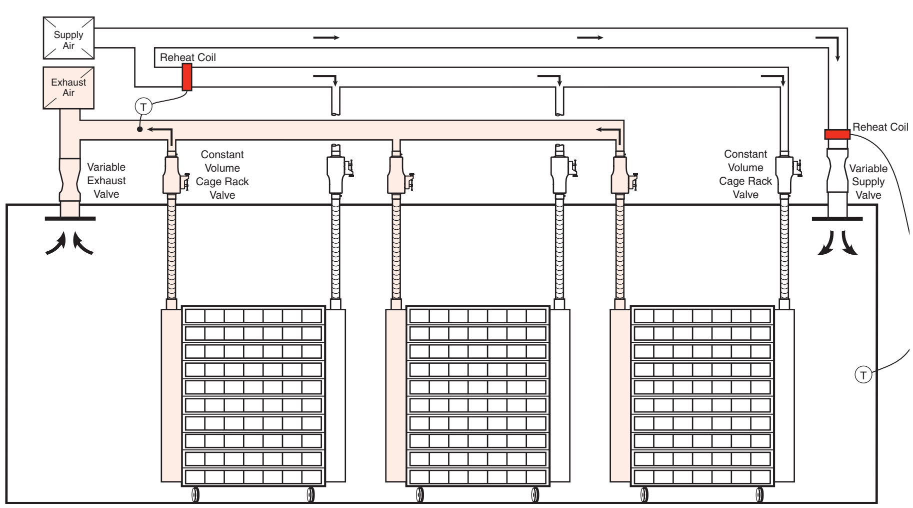


Figure 2-15. Dual supply air system. *Sensing and controlling cage temperature is not as simple as it may appear. Cage rack exhaust is a blended airflow, often with less than 50% cage air, complicating the temperature control and alarming.*

4. *Ability to sense and alarm high and low temperature limits properly*

   Most engineers who consider or use the dual supply air system today rely on temperature sensing in the exhaust duct serving the racks, even though it is a mixture of mostly room air. The major problem with this sensing location is the difficulty to accurately monitor and control the animal's environment. *More specifically, the inability to sense excessive cage temperatures early enough is the greatest concern with dual supply air systems*. Excessive cage temperatures must be avoided and alarmed quickly since *high temperatures kill animals* much more quickly than low cage temperatures. The systems must be properly sequenced to handle this situation.

   A separate temperature sensor in the supply duct near the duct penetration of the room to sense excessive temperatures is a good safeguard for alarming and to close the reheat valve. NOTE: If the dual supply air system is used, the reheat valve should fail *closed*, not open.

   Imagine this sequence with the dual supply air system: Worker X likes the room nice and cool because he/she is moving 1000-lb (450-kg) racks. The room's temperature is commanded to 68 °F (20 °C) and the cage's temperature is 75 °F (24 °C), based on the cage rack leaving air temperature set point. The temp sensor in the rack exhaust duct soon begins to sense approximately 71 °F (21 °C) and, therefore, opens the reheat valve to increase the supply air temperature to the cages. Even if there is a sensor in the supply duct to alarm what will become a dangerous situation, this is a possible scenario that could create devastating results.

   Using conditioned room air with a *room supply fan* virtually eliminates overheating situations since room alarms are more reliable and a better early warning system than a mixed temperature rack exhaust sensor. The room is a large buffering reservoir for temperature fluctuations that occur in the control loop. This important temperature buffering does not occur when the air enters the cages directly from the dual supply air system.

5. *Distance of HEPA filters from the animals*

   HEPA filters should be located as close as logically possible to the area or organisms that are to be protected. In this case, it is the rodent cages.

   Although the cages include a fine mesh filter that protects the animals, for a majority of the cage racks sold today, the path of supply air does not pass through this thin film. Therefore, the cage filter top cannot be used as an excuse to eliminate higher efficiency capture upstream of the cages.

   If the dual supply air system is the method used, HEPA filters in the air handling unit are often hundreds of feet from the holding rooms and the potential for contamination may be too high.

   Using a *room supply fan* with HEPA filters that continuously remove air impurities closer to the animals simplifies this strategy and maintains a lower particle count in the room and cages.

Using conditioned room air with a room supply fan virtually eliminates overheating situations since room alarms are more reliable and a better early warning system than a mixed temperature rack exhaust sensor.

6. *Overcoming the additional static pressure from zone HEPA filters in a central system*

   Loaded HEPA filters can contribute over 1" WC (250 Pa) of pressure drop in a building's air distribution system. The additional horsepower and costly system requirements to overcome this restriction may result in excessive first and operating costs. This affects the main air handling unit, fans, ductwork and other system components and may also generate significant acoustical problems or remedial costs.

   Room supply units reduce the number of supply fans and filters per room or per suite compared to Options #1, 2 and 3, but deal with this issue much more effectively. Preventative maintenance (standard intervals for replacing pre-filters) and pressure alarms address loaded filters.

Low Flow Racks or Multiple Racks per Valve

This section addresses the control of flows for racks requiring less than 30 CFM (50 m^3/hr) or where space constraints require multiple racks per valve.

The supply flows for 96-144 double-sided cage racks (the most common sizes) provided by the three most common manufacturers—Allentown, Lab Products, and Thoren—are in the range of 30-60 CFM (40-70 air changes per hour), depending on the manufacturer and design air change rate. Many projects in design today are using single-sided racks (those with cages on only one side), some of which require less than 30 CFM of *supply* air per rack. These racks are outside the flow ranges of the Phoenix Cage Rack Valve and require a different flow strategy, normally by using multiple racks per valve as shown in Figure 2-17 or with either Option #2 or 3 discussed earlier in this chapter. The airflow on the exhaust side of these smaller racks is still high enough to control one rack per Cage Rack Valve, resulting in improved stability and flexibility.

When space or design decisions result in a valve that is ducted to multiple cages, the rack manufacturers provide devices known as *load simulators* at each flex drop to the racks. Examples of these are shown in Figure 2-16. These devices are typically integral to the collars and are attached to the flex drops that serve each rack. When racks are disconnected from the manifolded building duct, the load simulators generate the same static load to the duct system as the connected racks generate.

Load simulators are not required on systems that are controlled using one Cage Rack Valve per ventilated rack, because Phoenix valves compensate for pressure changes automatically.

Figure 2-16. Load simulators. *When racks are disconnected from the building system, load simulators contribute the same static load as connected racks.*

Photo courtesy of Allentown Caging Equipment. Co., Allentown, NJ

Photo courtesy of Lab Products, Inc., Seaford, DE

The greatest disadvantages of this approach are balancing at start-up and the system imbalance when someone decides to adjust a manual branch damper. The balancing requires a skilled and patient balancing contractor since manual dampers are used to control flows as low as 10 CFM (17 m³/hr) per rack, which equates to a face velocity of 114 ft/min (0.06 m/s) in a 4" (100 mm) diameter duct. Accurately sensing this flow may be a challenge. Controlling it is another matter altogether.

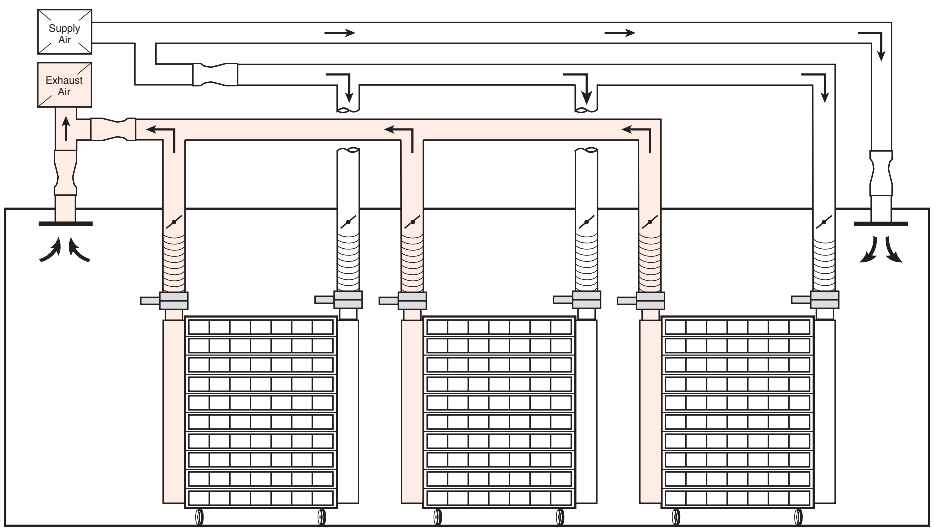


Figure 2-17. A manifolded system with multiple racks per airflow valve. *This method requires additional balancing and load simulators for each drop to the racks.*

Advantage:

- Lower first costs

Disdvantages:

- Difficult start-up procedure
- Ongoing balancing issues
- Higher probability of improper flow adjustments
- Flow adjustment of one rack affects all other racks on the manifold. May require rebalancing all racks.

Installation of Cage Rack Valves

Cage rack valves can be mounted in a variety of locations:

1. Interstitial spaces
2. On ventilated racks
3. On shelves in the rodent holding rooms

The interstitial space above the corridor ceiling is the most desirable location due to access and simplified cleaning of the holding rooms. Two goals in lab animal facilities are to:

- Keep as much equipment outside the holding rooms as possible.
- Minimize ceiling and wall penetrations as much as possible. Cracks, crevices, etc. in animal rooms can very easily become breeding areas for bacteria, viruses and other health and research threats.

For additional installation details, refer to the Installation section of the Cage Rack Valve Product Data Sheet on pages 77-78 in Chapter 5.

Animal Room Airflow Control

This section will review airflow control issues critical to creating safe, stable and reliable vivariums. Historically, vivarium spaces have required excessive service in order to maintain suitable control. Balancing and rebalancing has often been an ongoing task. To overcome these problems and better achieve the objectives, several important control issues must be addressed.

Reliable and Accurate Airflow Control Devices

> "Special consideration should be given to the ventilation system…Criteria for selecting mechanical systems and equipment should be based on reliability, operational integrity, projected length of service, and ease of maintenance."
>
> *–Occupational Health & Safety in the Care and Use of Research Animals (ILAR), pp. 107-108*

The depth of research and life-safety issues in these facilities demands reliable airflow control components different than those used for commercial office buildings. Controlling flows accurately for temperature and pressurization is critical.

Figure 2-18. A dirty flow probe. *Animal facilities generate significant dust, dander, and other airborne particulates, especially on the exhaust side. Dirty airflow probes affect room air change rates, room pressurization and temperature control.*

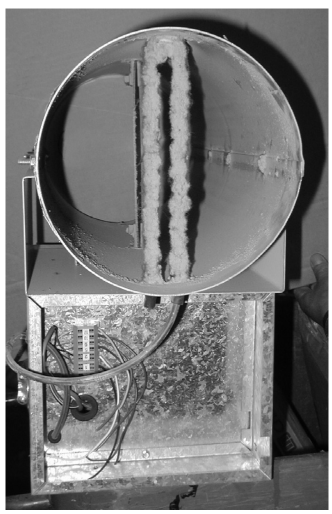


Photo courtesy of Moe Dion

Airflow control components must:

- Maintain accuracy in dander-filled airstreams
- Operate accurately without long straight duct runs
- Control continuously during a power failure
- Require minimal or no preventative maintenance
- Provide stability without the need for rebalancing or recalibration

Flow controls that rely on pitot tubes, orifice plates or other flow-measuring devices have few or none of the above characteristics. *Therefore, commercial grade boxes are not appropriate for laboratory animal facilities.*

> The use of traditional blade dampers and boxes for animal facilities has proven to be less than ideal because these devices:
>
> - Lack accuracy and repeatability required for tightly controlled rooms
> - Require periodic recalibration
> - Require periodic cleaning of airflow probes
> - Require a longer straight duct than is typically available
> - Require costly emergency power
> - May require periodic auto-zeroing (causes room to go out of control temporarily)
>
> **The Phoenix Controls Accel II valve is the reliable and accurate airflow control device that solves these problems.**

Installation in Congested Spaces

Since animal rooms must be free from mechanical equipment to the greatest extent possible, most environmental control devices are located in the interstitial space (above the ceiling). Building components commonly found in this space include:

- Mechanical system ductwork
- Electrical wiring and conduit
- Lighting fixtures
- Mechanical system piping
- Plumbing piping
- Sprinkler piping
- Communications equipment and wiring
- Building structural members
- Suspended ceiling support members
- Miscellaneous devices not listed above

Photo by Frank Hoek

All of these devices, ducts, pipes and wires crowd interstitial spaces, making it difficult or impossible to provide the required straight runs of duct upstream and downstream of terminal boxes that are critical for them to operate according to the manufacturer's catalog data. This is another reason why the typical airflow measurement devices, such as pitot tube, orifice rings, thermal or other point specific sensors, are poor candidates for these applications.

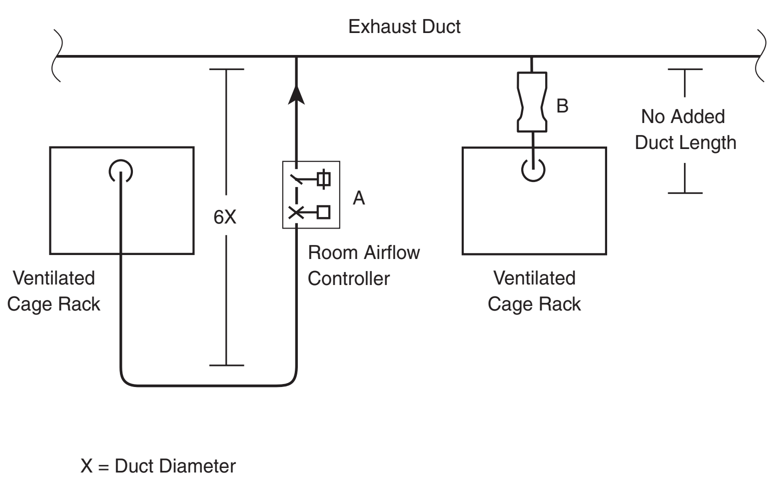
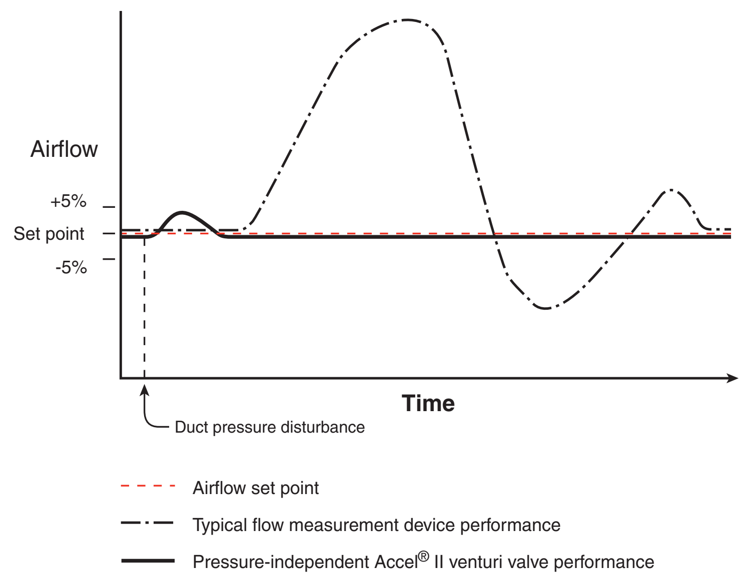


Figure 2-19. Installation requirements. *The traditional flow measurement device (A) requires laminar flow—adding several diameters of straight duct lengths upstream and downstream of the device. Airflow control devices (B) that do not have such limitations are desirable for tight installations.*

Pressure-independent Control

Not all pressure-independent devices are created equal. This is a critical point, since room pressurization may require only a small difference in flow, perhaps less than 30 CFM, between supply and exhaust air to the room. The amount of flow required to maintain the desired magnitude of pressurization depends heavily on the architectural tightness of the room, as previously discussed. The controls supplied with a terminal box are not often able to control accurately and quickly enough to maintain pressure when there is a change in the system static pressure.

Figure 2-20. Set point control stability. *Flow and pressure measuring devices require much more time to regain control than venturi valves require.*



Although the *Guide* is clear in stating that animal rooms need a dedicated ventilation system, renovated areas in older institutions are converted into animal spaces and use the same exhaust fan and duct system that is used for other laboratories in the building. Balancing each duct branch can be problematic in these situations due to the variation in duct pressures throughout the system. High-performance pressure independent venturi valves solve this problem.

Problems Associated with Commercial-grade Flow Controls	
• Slow response time	• System never seems to reach a steady state
• Lack of flow	• Improperly balanced hard-ducted ventilated racks
• Rooms fail to stay balanced	• Surging of flows (“breathing building” syndrome)

All of these problems can be greatly reduced or eliminated with the use of high-performance pressure-independent controls.

Quickly responding pressure-independent devices, such as the Phoenix Controls venturi valve, solve these balancing problems since the stable airflow devices react almost instantaneously to changes in duct static pressure. Other techniques, such as enlarging the ductwork to reduce duct static losses, can also help reduce these oscillation problems. However, these changes can be expensive, difficult to implement, and are entirely unnecessary when a high-speed control system is readily available.

System Flexibility

The NIH *Vivarium Design Policy and Guidelines* state that "the HVAC system must be capable of maintaining…a safe and comfortable environment for animals, be adaptable, and be capable of maintaining environmental conditions in any of the holding rooms for any of the species anticipated to be housed in the facility (p. D-15)." In other words, the HVAC system in a vivarium must allow for *flexibility*.

When there is a change from one species to another in a facility, many rooms can be affected, including holding rooms, procedure rooms, storage rooms and cage washes. The airflows required to accommodate these changes may vary dramatically, requiring the flow control devices to have a larger turndown ratio (max:min ratio) and more accurate control. As discussed earlier in this chapter, traditional blade dampers and flow measurement devices are not desirable when high demands for flexibility of flow ranges and repeatability are required. A high performance, pressure independent venturi valve offers the greatest flexibility.

Flexibility Demands Switchability	
Requirement	**Description, Example of Modes**
Multiple modes	Positive/negative/occupied/unoccupied/fumigate/purge*
Function change	Storage to Holding, Large Animal Holding to Surgery…
Non-human primate	(-) to Specific Pathogen Free Rodent (+)
Outbreak response	Prevent spread of contagions (switch to negative pressure)

* *An outbreak of a pathogen or certain parasites may require fumigation (minimal flow) and purging of rooms.*

Redundancy and Emergency Power Operation

The best solution for flow control during power interruption:
Install flow control devices that do not require power to maintain proper control.

Laboratory animal rooms must be maintained at a constant stable condition around the clock, even if electrical power is interrupted or if maintenance is required. This requires the use of redundancy of the critical components of the HVAC system. The system must be capable of maintaining the temperature, relative humidity and other parameters that affect the stability of the animal's environment. Exhaust fans, supply air handling units, boilers, pumps, and controls are among the system components that require redundancy and must also have emergency power during a utility power failure.

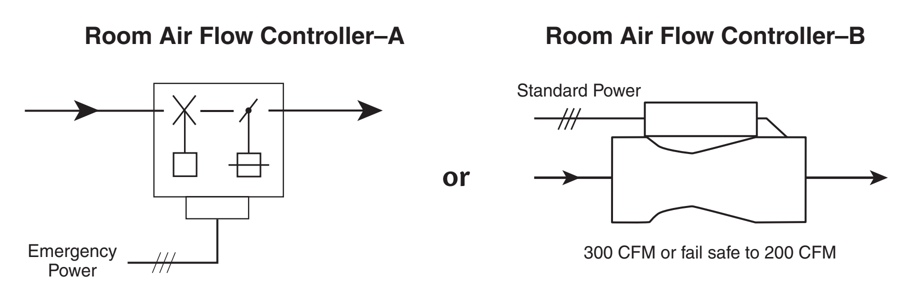


Figure 2-21. Fail-safe operation. *Room air flow controls must be on emergency power for operation during power failure (A) or fail safe to a fixed flow (B).*

Ventilation Requirements

HVAC Redundancy

Animal research facilities shall be designed to operate at a reduced level in the event of partial HVAC failure (ILAR, p.76). From an airflow design, the supply and exhaust systems would require emergency power for operation during power outages. Since total redundancy is seldom practical, a common approach to system design is multiple fans, each sized at partial load. In the event of power loss or service, one fan for the supply and exhaust systems is enabled by emergency power—allowing for partial air flow (e.g., 66%).

The room level controls must also be considered for emergency power conditions. The room air flow terminal devices must maintain flow control and pressure-independence with emergency power or must mechanically fail to a reduced set point. In Figures 2-21 and 2-22, a Phoenix Controls two-state air valve is used to default to the reduced flow on a loss of power. This saves significant emergency power loading since power is not required for the devices to function properly.

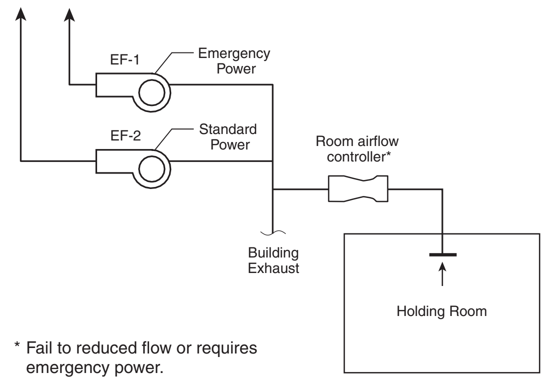


Figure 2-22. Emergency operation. *Systems must be designed to operate at reduced levels under emergency operation. Redundant fans with partial emergency power is typical. Controls must either fail to a reduced flow level or receive emergency power. Supply side systems must be similar.*

The NIH *Research Laboratory Design Policy and Guidelines* (p. D-25) require ventilation systems to operate at a reduced flow during power loss and further states that ventilated animal cages must be connected to emergency power. Reduced flows ideally are allocated such that non-essential areas (storage and some procedure rooms) would receive little or no flow so that essential areas (especially holding rooms) are not affected. In applications where the cage racks are connected to the building exhaust system, the exhaust control device connecting the rack to the building system must be operable during emergency power mode. The Phoenix Controls valve is ideal for this application since it does not require power or pneumatic air to maintain the correct preset reduced flow.

Fail-safe Requirements	Phoenix Controls Valves	Other Valves
• Auto fails to predetermined flow on power loss	Yes	No
• Extra wiring required	No	Yes
• Extra tubing required	Yes	Yes

Phoenix airflow control valves are self-balancing and auto fail-safe, which eliminates the need for emergency power for all room airflow control devices.

3

This chapter offers a complete description of the Accel II air valves. Phoenix Controls offers total control and flexibility to meet the demands of laboratory animal environments.

Table of Contents

Accel® II Air Valve

Airflow Control Valve Operation

The Phoenix Controls Accel II venturi valves combine a mechanical pressure-independent regulator with a high-speed position/airflow controller to meet the unique requirements of vivarium airflow. These valves can be used in VAV, as well as constant volume and two-state applications.

Pressure Independence

All Phoenix Controls valves maintain a fixed flow of air by adjusting to changes in static pressure. Each valve has a cone assembly with an internal stainless steel spring. The custom engineered springs were selected based on passing one million cycles of full-deflection testing. The cone assembly adjusts the open area of the venturi to system pressure as described below so that the flow set point is maintained continuously and instantaneously.

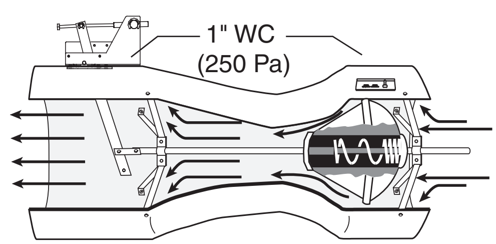


Figure 3-1. The effects of low static pressure on a venturi valve cone. *When there is low static pressure, less force is applied to the cone, which causes the spring within the cone to expand and pull the cone away from the venturi. The combination of low pressure and a large open area provides the desired flow.*

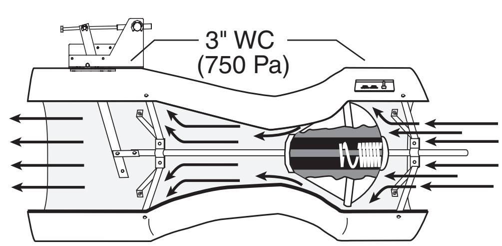
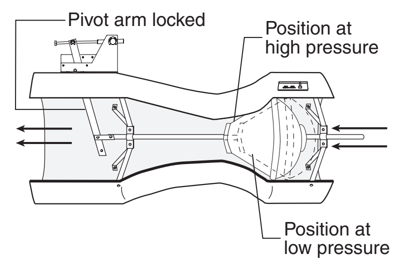


Figure 3-2. The effects of high static pressure on a venturi valve cone. *As static pressure increases force on the cone, the spring compresses and the cone moves into the venturi, reducing the open area. Higher pressure and the smaller opening combine to maintain flow set point.*

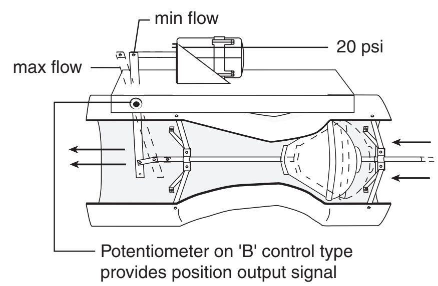
Valve Types

With the internal pressure independent cone assembly in operation, airflow can be regulated by positioning the shaft/cone assembly. The following types of Accel II valves are available:

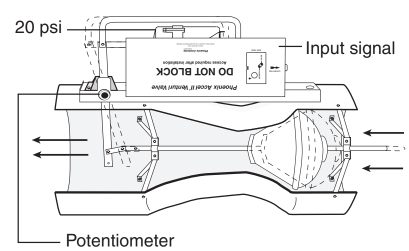
- Constant Volume: The valve's shaft is adjusted and then locked into a specific position, which provides the scheduled airflow via factory calibration.



- Two-state: The valve's actuator positions the shaft to two distinct airflows. Mechanical clamps assure precise minimum and maximum airflows via a factory preset.



- VAV: Closed-loop airflow control via flow feedback to command. The shaft is positioned using direct potentiometer measurement to produce a linearized factory characterized feedback.



Valve Construction

Applications require that each valve be built to withstand unique environments. The Accel II valves are available in three construction types and four valve designs.

Construction Types

- Class A: Non-corrosive atmosphere—supply air, return air, and many general exhaust applications.
- Class B: Corrosive environments—general chemical fume exhaust.
- Class C: Consult the factory for special coatings.

Valve Designs

- A: Conical-shaped diffuser (standard Accel II valve)
- S: Standard Shut-off Valve
- L: Low-leakage Shut-off Valve
- C: Compact valve body

Specifications for the Accel II valve are included in Chapter 5, System Components.

This chapter reviews control and monitoring approaches for vivariums. It also provides recommendations for environmetal control and integrating airflow control systems in vivariums.

Table of Contents

4 Control Applications

Deciding how to best control the airflow in a vivarium depends on many factors. Stability, flexibility, safety, energy use, installation costs and operating costs are a few of the issues that must be considered. These factors will affect the type of ventilation control application selected for a vivarium.

This chapter describes the control applications used in vivariums, and recommends environmental control solutions for each application. The topics covered are:

- Where control applications are used–Provides an overview of the common classes of airflow control applications used in modern research laboratories
- Airflow control considerations in vivariums–Reviews the typical airflow control needs in an animal research laboratory
- Environmental control solutions–Describes the environmental controls approaches available from Phoenix Controls and the benefits of each
- Integrating laboratory airflow control systems–Describes the benefits of integrated laboratory airflow control systems

Where are Control Applications Used?

Control applications are used in a wide variety of environments. Examples of these environments related to research include:

- Adjacent spaces
- Life sciences laboratories
- Vivariums and biosafety level 2 (BSL-2) laboratories
- High-level BSL-3 containment laboratories

Each of these environments require different control strategies and Phoenix Controls has a solution for each. For more details, see the "Environmental Control Solutions" section on page 40.

Adjacent Spaces

Adjacent spaces–offices, corridors and stairwells–may seem less critical in precisely controlling airflow. But in reality, every adjacent space affects the ventilation throughout the building.

- The air pressure in offices and support spaces in and around the laboratory spaces is typically positive. Positive pressure prevents undesirable odors in the research areas from permeating offices and support spaces. Also, positive pressure often contributes to the volumetric offset of the labs. Providing personal temperature control for offices and support spaces contributes significantly to the occupants' comfort and efficiency.
- Corridors provide offset flow into and out of offices and lab spaces. Precise airflow control of the corridors in and around lab spaces is required to ensure the pressurization inside critical spaces is never compromised.
- Stairwells also contribute to the offset air for laboratory spaces and often are used as "safe havens" in the event of an emergency. Ensuring the stairwell is pressurized relative to the floor and the ability to shut off supply air in the event of a fire, or control airflow at a high rate to purge smoke or offensive odors from stairwells, promote safe access to and from the floors with functioning lab spaces.

Life Science Laboratories

Life science laboratories are typically biology or physics labs in which research is conducted in an open area, such as a benchtop, instead of inside a fume hood or biosafety cabinet. If fume hoods or biosafety cabinets are used, ventilation is usually controlled with two-state or constant volume airflow devices. Ventilation and volumetric offset are important for removing offensive odors from the research areas, and preventing odors from migrating into adjoining offices and corridors. Precise temperature and humidity control tends to be more simplistic in these spaces but somewhat more critical, because most research is conducted on an open bench in a large open environment.

Vivariums and Biosafety Level 2 (BSL-2) Laboratories

These laboratories are often made up of a suite of spaces that may include animal holding areas, procedure rooms and necropsy rooms sharing a "clean corridor." These suites often contain one or more ventilated cage racks, and may include biosafety cabinets or constant volume fume hoods. Precise ventilation rate adjustments and accurate temperature and humidity control are required for the health, safety and comfort of the animals, researchers and caregivers. Since volumetric offset is used to contain and isolate these spaces based on the nature of the research, it is often necessary to change the pressurization from negative to positive or to change the ventilation rated based on the type of research conducted. These offset changes must be accounted for in the ventilation and offset control functions of the clean corridor.

High-level Containment Laboratories

High-level containment laboratories, which often require precise temperature and humidity control, are often classified as biosafety level containment 3 (BSL-3) or higher. Pharmaceutical cleanrooms also fall under the high-level containment category. These spaces may be validated GMP facilities, which require constant monitoring and trending of all environmental characteristics.

High-level containment laboratory spaces are built to be as aitright as possible. Environmental control is often based on differential pressure instead of volumetric offset. Airflow is controlled through an airlock or anteroom providing a buffer zone between the research space and adjacent common areas. Ventilation rates are typically higher than other types of laboratories, and complex control and alarming sequences are common. Biosafety cabinets and constant volume fume hoods may also be present in these labs.

Airflow Control Considerations in Vivariums

Typical airflow control considerations in vivariums include:

- General supply and exhaust devices to maintain minimum ventilation rates, pressurization and space comfort control
- Shut-off supply and exhaust devices to accommodate gaseous decontamination or isolation of space
- Cage rack supply and exhaust devices, typically set at a fixed flow based on the size and design of the racking system
  - Most of these systems are connected to the building supply and exhaust systems.
  - Some designs draw air from the room, while others exhaust to the room through HEPA filtered exhaust ports.
- Biosafety cabinets, mostly recirculating types; however, some are connected to the building exhaust system
- Point-exhaust or "snorkel" devices
- Down-draft necropsy tables
- Cage rack and cage wash systems

Airflow Control Applications Used in Vivariums

These airflow control applications are commonly used in vivariums:

- Constant volume suites
- Switched constant volume suites
- Variable air volume with temperature control
- Variable air volume with temperature and relative humidity control

Each of these applications is discussed in more detail below.

Constant Volume Suites

Constant volume control is the most common strategy for animal rooms. This is because of the continuously high heat loads and demands of equipment that operates around the clock. Although constant volume control is a simple, straightforward approach, most facilities experience problems with it because equipment and building conditions change over time, causing differences in the operation of the ventilation system. Even minor changes, such as worn fan belts and partially loaded filters or dust on flow measuring devices, can create major flow and pressure problems throughout a building. High-performance, pressure-independent airflow control devices ensure stable constant airflow for many years.

Generic Constant Volume Suites

Generic constant volume suites use manually adjustable fixed blade dampers to set the animal room's make-up air and general exhaust rates. These are pressure-dependent devices that will not compensate for changes in system pressure. The make-up air damper is set to deliver the desired number of air changes per hour in the room and the general exhaust is adjusted to a slightly lower (or higher) flow to provide a positive (or negative) pressure in the room. Temperature control is normally achieved by reheating the conditioned air. *This is an outdated, undesirable approach since the pressure-dependent dampers do not actively control the flows in the room.* Pressure fluctuations in the ventilation system will change the

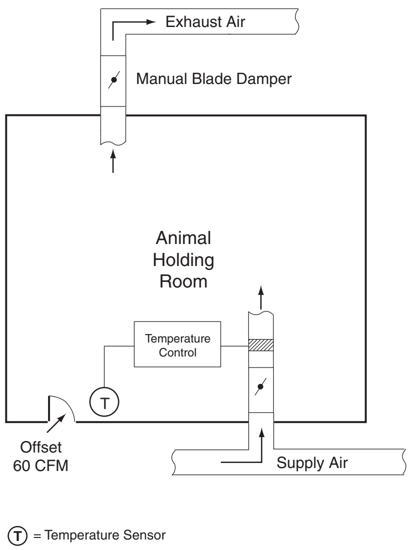


Figure 4-1a. Generic constant volume animal room. *This approach uses single blade dampers, which do not compensate automatically for system pressure fluctuations.*

flows and climate throughout the entire system and will fail to maintain appropriate levels of pressurization in the facility.

Advantages

- Straightforward, simple design
- Low cost of controls

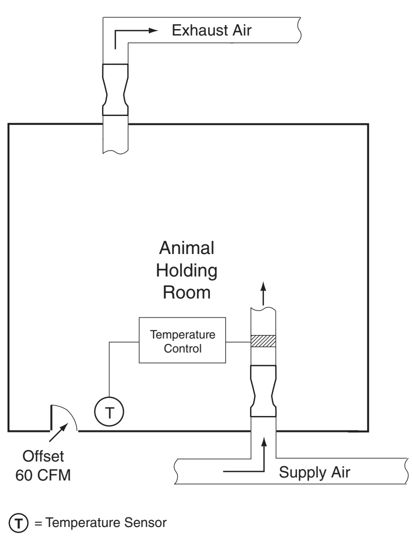
Disadvantages

- Stability, safety and comfort are compromised because the system is pressure dependent. Changes and fluctuations create improper flow rates and pressurization problems. Rebalancing is required at every damper location when changes are made or fan system performance degrades.
- The system must be rebalanced frequently.
- Low flexibility, as future expansion and changes required for different animal populations are limited
- No inherent monitoring or alarming
- High energy use from continuous full flow operation

Constant Volume Room Control with Phoenix Controls Valves

For each room, pressure-independent valves maintain a constant supply and exhaust airflow. As a result, room offsets remain constant. Exhaust devices are connected to the house exhaust using constant volume valves. The Building Management System (BMS) controls the temperature and relative humidity.

Figure 4-1b. Phoenix constant volume air valve operation. *As system static pressure fluctuates, each valve adjusts its pressure-independent cone assembly to maintain a set airflow.*



Benefits

- Accurate, stable flow control
- Costly emergency power not required to maintain the correct flows during power loss mode
- No preventive maintenance required
- Eliminates rebalancing—The system is pressure independent and maintains steady flow through system changes, filter loading and HVAC system degradation

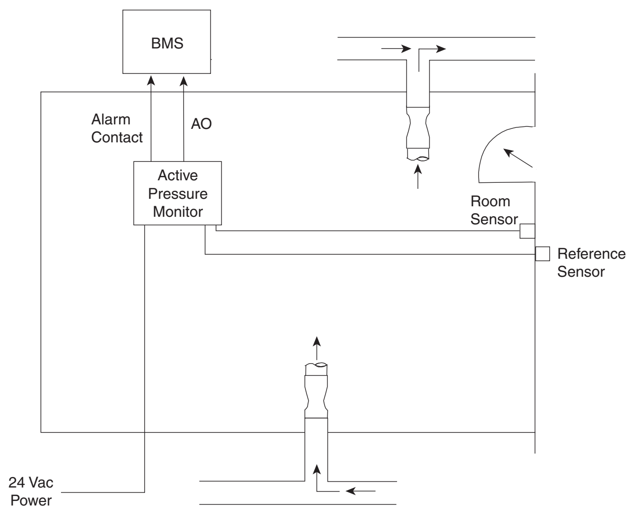


Figure 4-1c. Constant volume room application. *Phoenix Controls' pressure-independent valves maintain constant supply and exhaust airflow. As a result, room offsets remain constant. Pressure is monitored between the critical space and a relevant reference space.*

Local differential pressure alarming is based on a field-configured pressure set point. A form C relay is available for remote alarm monitoring and an analog output is available for monitoring differential pressure remotely.

Constant Volume Boxes Compared to Phoenix Constant Volume Valves

The value of research animals is staggering. For example, foundation animals of a transgenic mouse colony may be worth tens of thousands of dollars* or more. Their offspring may be in one small holding room with four or more ventilated racks, where each rack is capable of housing as many as 700 mice. Although the total value of animals in a holding room can be in the millions of dollars, decisions on ventilation controls are sometimes made to save a few hundred dollars. Often, these upfront "savings" become long-term aggravations in attempts to control a stable environment.

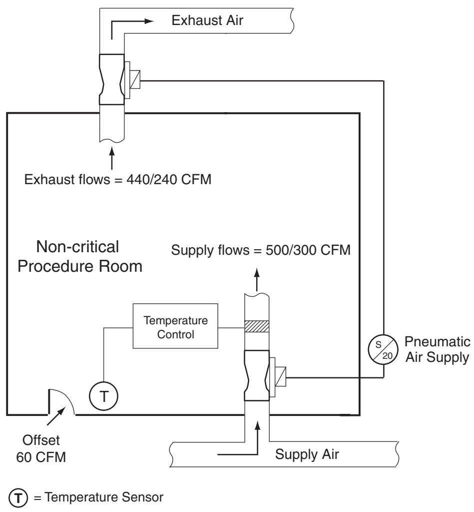
A popular approach for controlling animal rooms uses single-blade dampers with pitot tubes, orifice plates or other flow or pressure measuring devices wired to a terminal unit control module. These are most commonly known as constant volume boxes or terminal boxes, and may be chosen because of lower first costs. Unfortunately, these boxes lack the advantages of other flow control devices that do not require rebalancing, recalibration, cleaning, emergency power or straight runs of duct for proper operation. Ventilation control components that solve these problems justify additional investment, especially when research costs and future operating costs are factored into the value of the system.

Functionality	Constant Volume Boxes	Phoenix Controls Valves
Balancing	Require adjustment, more costly	Factory set, saves time
Rebalancing/recalibration	Required periodically	None required
Regularly scheduled maintenance	Require preventative maintenance	None required
Dust and dander in airstream	Measuring devices require cleaning	Not affected by typical conditions
Straight duct	2-3 duct widths up and downstream	None required up or downstream
Auto-zeroing	Room goes temporarily out of control	Not part of control sequence
Turndown ratio (maximum: minimum)	3-3.5:1	Approximately 20:1
Accuracy	15% of command at low end of range	5% of command
Emergency power	Requires emergency power	Auto-fails to correct flow without power
Cage rack ventilation options	Lack accuracy and repeatability	Proven accuracy and reliability
BMS data points	BMS controller integral with box	Points via room or building network

*The foundation animals of a transgenic (TG) or knock-out (KO) strain serve to maintain the genetic integrity and stability of the strain over a period of time. The expense of establishing a TG/KO strain of mice can be exorbitant, sometimes requiring multiple attempts to successfully insert or knockout the desired gene, and any cross and back cross matings to develop a stable line that will reliably express the desired genetic feature. Some KO strains can be so unique that once established, it is unlikely they could ever be exactly duplicated, making these animals invaluable, perhaps beyond hundreds of thousands of dollars. See http://www.research.uci.edu/tmf/ for a price list of service charges related to making transgenic animals.

Reduced-level Constant Volume: Low-cost Alternative for Controlling Emergency Power

Figure 4-1d. Phoenix reduced level constant volume control. *Phoenix Controls Model PEV and PSV valves automatically adjust flows to the correct, predetermined flow during loss of power. Costly emergency power is not required. Non-critical rooms (storage, offices, some procedure rooms) are reduced to lower flows, while holding and other critical rooms are maintained at the same flows.*

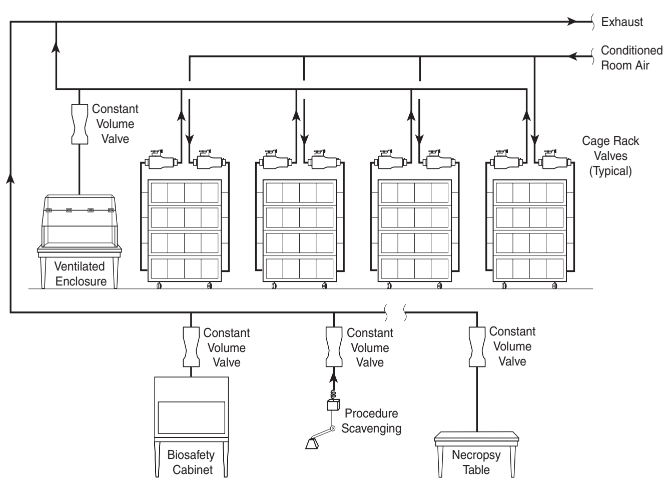


Benefits

- Costly emergency power is not required for Phoenix valves
- Automatically fails to safe, reduced flow
- Maintains proper room pressurization
- Automatically compensates for pressure fluctuations in duct

Normal mode	Air handling units (AHUs), exhaust fans and room-level air valves operate at full design constant volume flow.
Emergency power	AHUs and exhaust fans operate on emergency power to maintain flow at a reduced level. Two-position Phoenix Controls air valves are used (models PEV, PSV) to provide automatic fail-safe flow control. This sequence can also use Phoenix Controls' electrically actuated valves.
Phoenix Controls advantage	An emergency power connection is not required to default to reduced flow position and accurately maintain the reduced flow.
Box disadvantage	Each box requires costly emergency power to function properly in the event of a power loss.

Figure 4-1e. Additional constant volume control needs. *Constant volume valves maintain precise flow and eliminate the need for future rebalancing at each device.*



Switched Constant Volume Suites

The holding rooms can be switched at the room monitor between positive and negative pressure by switching the flow of supply (or exhaust) air. The internal corridor compensates for offset flow changes by adjusting the amount of exhaust (or supply) air. The procedure room is maintained at negative pressure. The airlock is maintained at positive pressure.

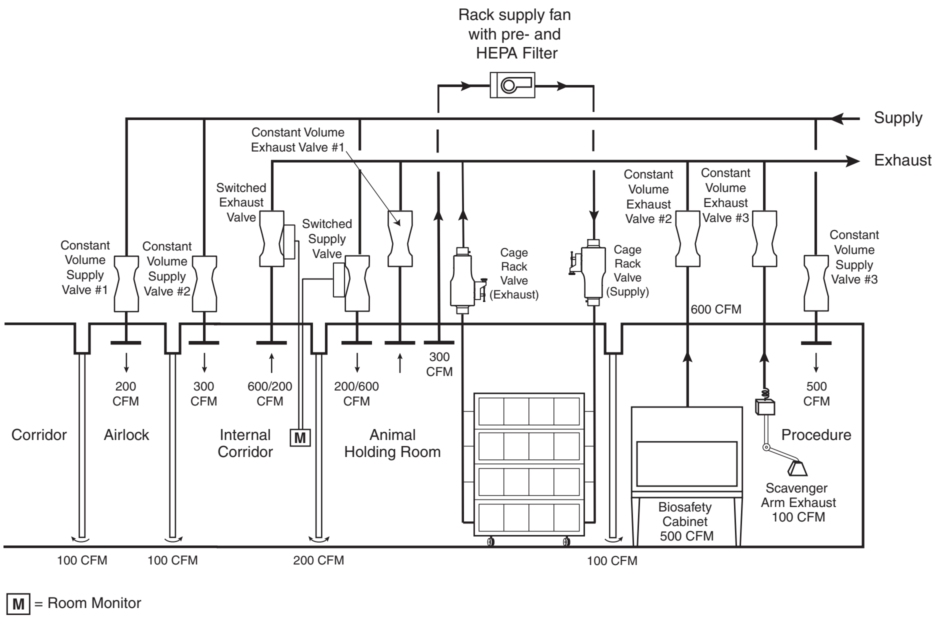


Figure 4-2. Phoenix Controls' switchable pressurization air valve operation. *As system static pressure fluctuates, each valve adjusts its pressure-independent cone assembly to maintain set airflow rate. Constant volume valves maintain one set flow, while switched valves operate as two-state controllers.*

Switched Constant Volume with Flow Alarm Input

Pressure-independent valves maintain a constant supply and exhaust airflow. One of these valves is constant volume and the other must be a two-position valve. A dry contact, supplied by others, triggers a DPDT relay, which switches the Active Pressure Monitor alarm set point to the equal and opposite polarity and switches the two-position valve, effectively changing the room from positive to negative pressurization and alarming or vice versa. Phoenix Controls Accel valves fitted with pressure switches provide a flow alarm input to the APM100. In the event of either a flow or differential pressure alarm, a form C relay is available for remote alarm monitoring. An analog output is also available for monitoring differential pressure remotely.

Benefits

- Repeatability of Phoenix valves provides reliable flow and offset control
- Stable pressurization control
- Simple, straightforward and convenient solution
- No preventive maintenance

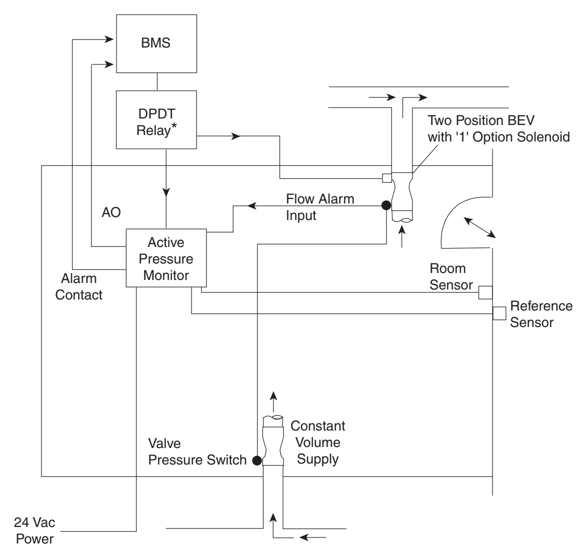


Figure 4-2a. *Switched constant volume with flow alarm input.*

* *RIB2401D or equivalent—Call Functional Devices, Inc. at (800) 888-5538 for your nearest RIB distributor.*

Uses for switchable pressurization:

- Reversible holding rooms for handling outbreaks
- Conversion of room for quarantine
- Change of species, e.g., Specific Pathogen Free (SPF) rodent to primate requires going from positive to negative pressurization

Switchable pressure design principles can be achieved with an electronic-based controller, which provides a shut-off option for gaseous decontamination in constant volume and switched constant volume suites.

Variable Air Volume (VAV) with Temperature and Relative Humidity Control

Temperature and humidity sensors provide feedback to a controller by the Building Management System (BMS) for analog integration or to a Phoenix Controls controller for digital integration systems, both of which are described later in this chapter. The room is maintained to a set point for temperature, and perhaps relative humidity, by adjusting the supply flow, reheat valve, humidifiers or other trim devices. Room pressurization is also maintained.

As discussed in Chapter 2, many laboratory animal spaces experience variable loads, such as changing animal populations, active/inactive procedure rooms, and cage wash operation periods. These spaces require proper pressurization, ventilation, temperature and humidity control. Phoenix Controls' Accel II valves offer superior control for these applications.

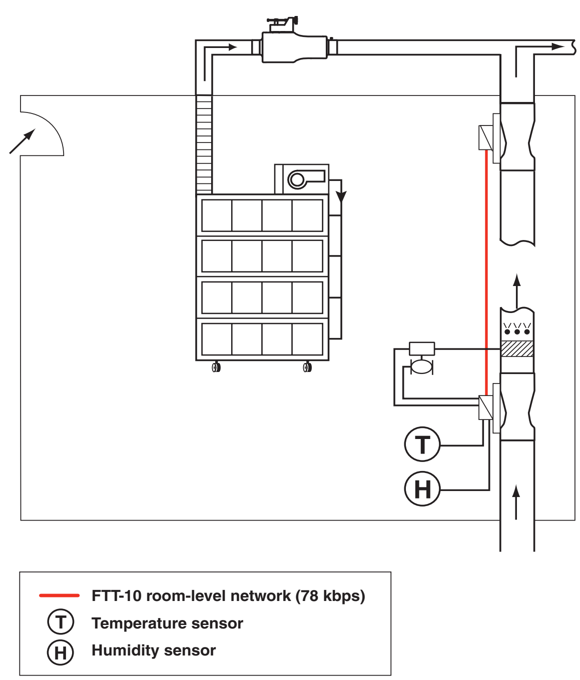


Figure 4-3. VAV air valve operation. *The pressure-independent valve cone assembly adjusts automatically for pressure fluctuations in the system, maintaining proper flows over the entire range of command. Thermal or ventilation requirements command the supply valve to the required flow, while the room's general exhaust valve adjusts to maintain room pressurization.*

Benefits

- Superior flow control with fast, stable adjustments
- Flow range can vary widely, as much as 20:1 turndown ratio
- Stable room pressurization maintained over large flow changes
- Eliminates rebalancing–The pressure-independent system maintains steady flow through system changes, filter loading and HVAC degradation
- No preventive maintenance required
- Low sound power levels
- Local temperature and humidity and sensing control with Phoenix Controls' Celeris Environmental Control System
- Option of shut-off valves instead of costly isolation or bubble-tight dampers for gaseous decontamination

VAV Control for Complex Vivarium Layouts

The room air change rate can be reduced with this flow pattern since its heat load, odor and other gaseous effluents are exhausted out of the room, rather than back into the room. This allows for a much more flexible, energy conserving approach.

The vivarium ventilation control system's goal is to stabilize the micro- and macroenvironments. This requires drawing clean, conditioned air into the space and removing dirty, heated, moisture-laden air, while maintaining proper room pressurization. Phoenix Controls' compact cage rack valves provide airflow control that ensures environmental integrity at the room and device level.

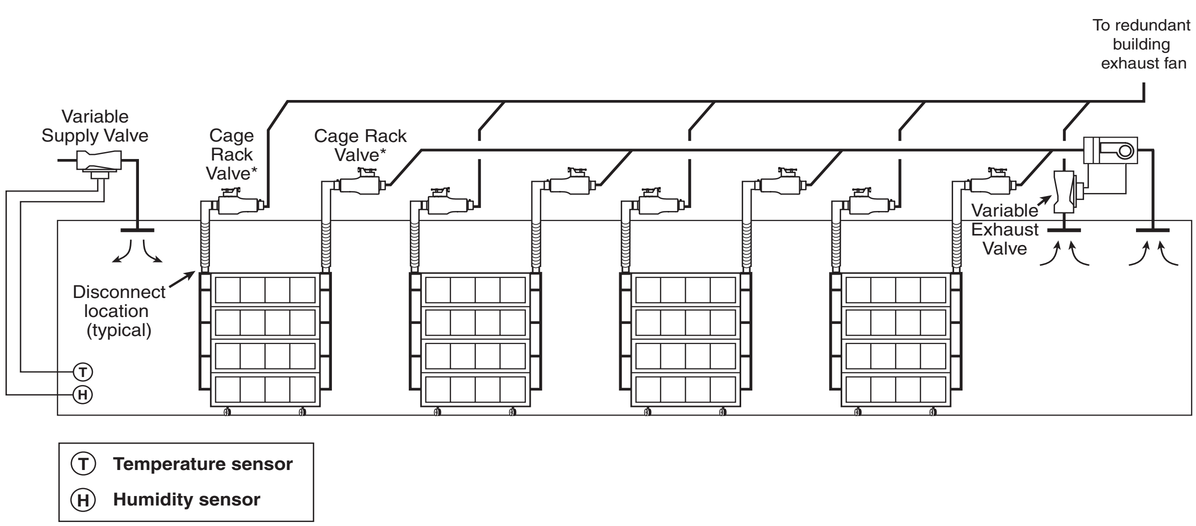


Figure 4-4. VAV for rodent holding rooms-air valve operation. *Thermal or ventilation requirements command the supply valve to the required flow, while the room's general exhaust valve adjusts to maintain room pressurization. Ventilated racks are maintained at a constant volume.*

Control Applications

Airflow Control for Rodent Holding Rooms

Phoenix Controls compact cage rack valves maintain precise constant airflow to and/or from the ventilated racks and eliminate the need for future rebalancing (see Figure 4-4). Our pressure-independent valves maintain the proper room supply and exhaust airflows to provide the correct ventilation rate (air changes per hour) and a constant volumetric offset to maintain proper room pressurization.

A variable air volume (VAV) room controller adjusts the supply airflow to the meet the room's thermal or ventilation requirements and adjusts the general exhaust airflow to maintain room pressurization. The room air change rate can be reduced with the flow control strategy shown in Fig. 4-4, since animal odor, other gaseous effluent and part of the heat load are exhausted out of the room, rather than back into the room. The VAV room and constant volume cage rack valve systems allow for a much more flexible and energy-conserving approach.

Temperature and relative humidity control is by Phoenix Controls or by the building management system, depending on the engineering design.

Refer to pages 13-23 for additional application information.

Benefits

- Phoenix valves stabilize the macro- and microenvironments, while reducing room air change rates to lowest possible
- Monitors cage rack and HEPA filter status
- Includes cage rack exhaust in zone control function

Environmental Control Solutions

The focus for vivarium design today is on flexible research space. The flexibility of the Celeris control system and the accuracy and high turndown ratio of the Accel® II venturi valve, allow the system to easily be reconfigured for changing research requirements through a few network commands or configuration alterations for:

- Air change rates–Based on the types of animals or research
- Polarity (negative or positive)–Based on the research conducted or the animals' health
- Supply or exhaust air–Based on the type and number of cages or racks
- Temperature or humidity set points–Based on the requirements of varying species of animals

As airflow or pressurization requirements change, there may be an impact on adjacent spaces that contribute directly to the balance of all adjoining spaces. For example, several animal holding or quarantine rooms in a vivarium suite

How flexible is the Celeris Environmental Control System?

The Celeris Environmental Control System is very flexible. Here are some examples of its scalability.

From	To
Adding a single Celeris valve controller to a space designed as constant volume for implementing specific control strategies or integrating lab data	Dozens of Celeris valve controllers functioning interactively to satisfy complex control strategies
Standalone, non-integrated systems	• Individual labs or groups of labs, seamlessly integrated to the BMS • Entire buildings with hundreds of valves and thousands of points seamlessly integrated to the BMS

may be switched between negative and positive pressure, depending on the research conducted. The common corridor must adapt to the changes in airflow. The airflow devices in the corridor must be sized to handle not only their own ventilation and cooling requirements, but also to supply offset air (assuming all animal rooms are negative) and absorb all offset air (assuming all animal rooms are positive).

Phoenix Controls offers a variety of products and systems that control airflow precisely and save energy in viariums. These products and systems are also designed to ensure all occupants–humans and animals–are comfortable and safe.

- Celeris® Environmental Control System and Traccel® Room Controller
- Standard or Low-leakage Shut-off Valves
- Accel® II Venturi Valve (see Chapters 3 and 5 for more information)

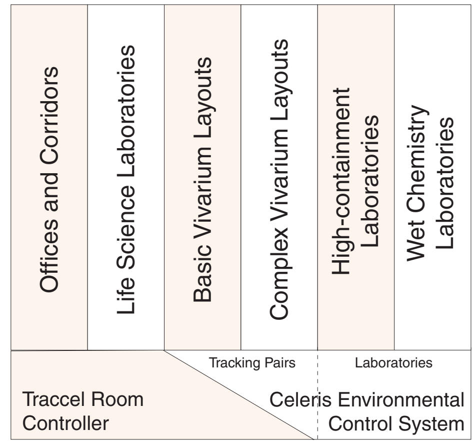


Figure 4-5. The Traccel Room Controller and Celeris Environmental Control are ideal in a variety of spaces and layouts.

Benefits of the Phoenix Controls Celeris Environmental Control System and Venturi Valve

- A high turndown ratio allows corridor to remain in control over the range (all rooms negative and all rooms positive) on top of corridor ventilation requirements
- Precision flow metering allows the corridor to respond accurately to a 200 CFM change in offset on a gross flow of 2500 to 3000 CFM total flow
- The pressure-independent Accel II valve maintains consistent flow with potential large changes in the suite's supply and exhaust demand, as well as any other changes on the common ventilation system
- The Celeris system monitors flow from adjoining spaces and adapts corridor flow automatically

Other products are also available. For more details, see Chapter 5.

Celeris® Environmental Control System and Traccel® Room Controller

The Celeris Environmental Control System is a cost-effective platform designed for ventilation control applications ranging from simple to complex. With flexible inputs and outputs (I/Os), highly configurable control schemes, scalable architecture, options for economical or high-performance actuators and downloadable firmware, the Celeris and Traccel systems meet any requirement for controlling critical spaces in today's laboratories, life science facilities, vivariums and cleanrooms.

This system provides a safe, comfortable working environment for research in a single standalone lab or an entire research complex. The flexibility, airflow turndown, and configurability make it the perfect solution for modular, mixed-use facilities.

The Celeris Environmental Control System has two levels of control:

- Celeris tracking pairs–Used for more complex room-level control seen in biology labs, animal holding spaces, procedure rooms and constant volume spaces requiring precise temperature and humidity control
- Celeris lab solution–Controls a single fume hood lab space containing up to 10 fume hoods, four independent temperature zones, and two associated office zones

The Celeris Valve Controller and Traccel Room Controller perform the valve flow position control and includes configurable I/O for connecting local control elements, such as sensors and actuators, for control and monitoring. The primary function of the controller is to perform precision flow control; however, at the time of commissioning, it is assigned specific room-level control functions. In general, these room-level control functions include:

- Zone balance control, which sums all of the networked, hard-wired and constant volume flow terms to maintain the desired air change rate, make-up air for fume hood, biosafety cabinet or cage rack demand and offset control for space pressurization
- Temperature control–Highly configurable cooling and heating control loops maintain a comfortable, precise space temperature
- Humidity control–Control loops for humidification and dehumidification maintain the space at a specific humidity set point (Celeris lab and tracking pairs only)
- Occupancy control allows the system to maintain precise control over the space when the space is in use. When the space is not used, this control adjusts ventilation and temperature settings to save energy.
- Emergency mode control allows a user to define alternate, event-driven control modes, such as decommission, purge, decontamination, supply fan failure, and exhaust fan failure, that may be initiated locally or through the Building Management System (BMS).

Celeris Valve Controller (CVC)

The Celeris Valve Controller (CVC) controls valve position by using one of several different style actuators and by monitoring the flow feedback signal for precision flow control. The room-level control scheme dictates the type of actuator required–high speed or normal speed.

- High-speed actuation is required in spaces where the system performs make-up airflow control of two-state or VAV fume hoods. Changes in sash position require one-second speed of response from the make-up air or general exhaust valves to maintain proper space pressurization. High-speed electric or pneumatic actuation with configurable fail-safe operation is available on the Celeris Valve Controller.
- Normal-speed actuation–In non-fume hood spaces, where changes in airflow are dictated by temperature and occupancy control functions, a more economical standard speed of response electric actuator is available. The Celeris Valve Controller and Traccel Room Controller support the 60-second electric actuator. Because make-up air control for high-speed fume hood is not required in these applications, a fail-to-last position fail-safe is appropriate.

The desired actuation must be specified at the time of the order. The electric actuators obtain power from the valve controller. The pneumatically operated valve requires a 20 psi pneumatic source.

The system uses the LonWorks communication protocol to develop distributed control or peer-to-peer control architecture to implement the desired room-level control strategy.

Traccel Room Controller

The Traccel Room Controller controls the valve position of the supply and exhaust valve by monitoring the flow feedback, and opening or closing each valve to maintain the desired ventilation rate and offset. The Traccel Room Controller uses an electric actuator that requires 60 seconds to travel from fully open to fully closed and is only offered with a fail-to-last position fail-safe mode.

The Traccel Control System offers three levels of control for normal-speed applications:

- The Traccel Tracking Pairs (TP)–An economical solution for tracking pair applications requiring precise ventilation, pressurization and basic temperature control
- The Traccel Enhanced (TX)–Same as the Traccel tracking pairs with the addition of extra inputs and outputs (I/Os) to control humidity and pressure monitoring, plus an optional shut-off capability
- The Traccel Supply-only (SO)–an economical solution for when a supply-only valve is required for an alcove or independent space. It maintains temperature and ventilation control and supports a reheat valve, if needed.

Control Sequences

Adjacent Spaces, Life Science Laboratories and Generic Vivarium Spaces

When the Celeris and Traccel systems are used in the constant volume, two-state and variable air volume (VAV) room control applications described earlier in this chapter, you can accomplish varying levels of sophistication in the control sequences.

- Implement local temperature control
- Implement various occupancy and alternate emergency mode control strategies
- Remotely change room polarity to manage animal environments
- Remotely change ventilation rates or temperature set points based on changing research requirements
- Collect supply and exhaust flow variables from non-networked flow devices and factor these flows into the ventilation and room balance control
- Use the Celeris or Traccel network to integrate this information to the BMS

Multiple Temperature Zones in Combination Research and Office Spaces

Sometimes in larger spaces, temperature gradients vary within the space. In these applications, multiple temperature zones can be used to provide local cooling where needed. In these applications, Traccel Controllers work together to sum the total supply volume for three temperature zones and modulate one exhaust valve to maintain correct directional airflow.

Life Science Laboratories

In this example, a Phoenix Controls Shut-off Valve isolates the biosafety cabinet (BSC) exhaust flow when it is not in use (see Fig. 4-7). The Shut-off Valve communicates over the room-level network with the Traccel Room Controller, which compensates for the change in flow to maintain room airflow balance and ensures correct directional airflow into or out of the room.

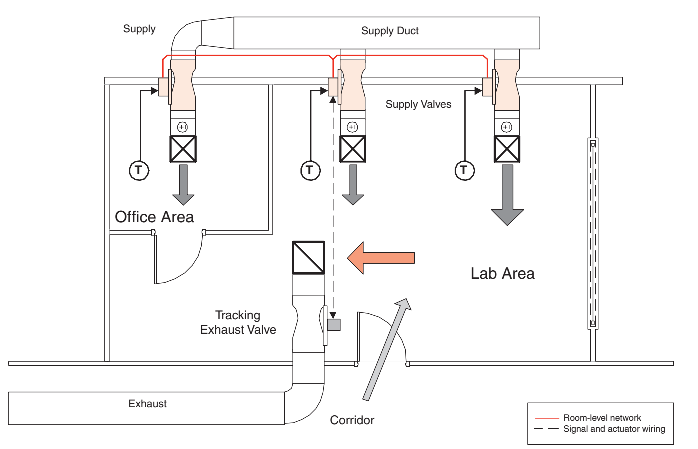
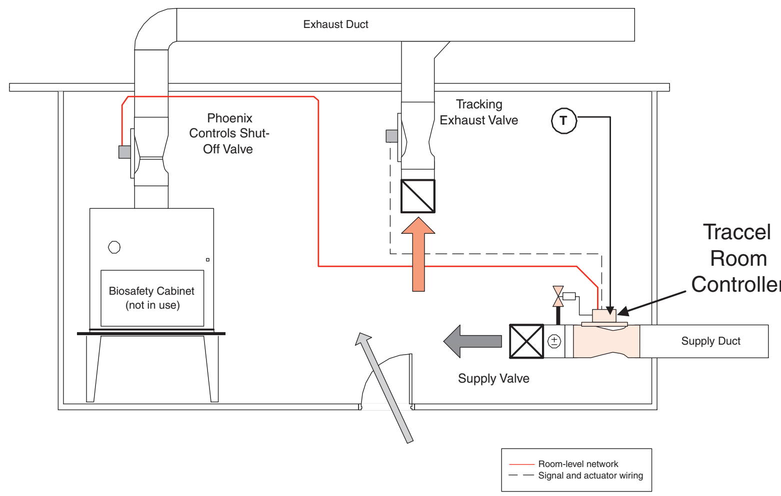


Figure 4-6. In this application, the Traccel Room Controller is controlling cooling in multiple temperature zones.

Control Applications

Figure 4-7. A life sciences application using the Traccel Room Controller and a Phoenix Controls Shut-off Valve.



Complex Vivarium Layouts and Biosafety Level 2 (BSL-2) Laboratories

In complex vivarium layouts and biosafety level 2 (BSL-2) laboratories, you can use the Celeris Environmental Control System to:

- Implement humidification and dehumidification control
- Deploy Shut-off valves on supply and exhaust systems for decontamination or decommissioning modes
- Monitor analog or two-state outputs from non-networked devices for control, alarming or integration. Examples include:
  - Temperature outputs from freezers, autoclaves or sterilizers
  - Pressure or temperature alarm outputs from freezers, autoclaves, sterilizers, or differential pressure switches detecting HEPA filter status
  - On and off states from biosafety cabinets, necropsy tables, cage rack fans, cage washers, cage rack washers, and autoclave or sterilizer cycles
  - Remote start and stop commands for equipment in each space, such as fan coil units

The Traccel Room Controller, or two or more CVCs connected on the room-level control network, implement a variety of control and monitoring functions. At the same time, devices can be added to achieve increasingly sophisticated control sequences. For example:

- To display data and editing set points locally, add a Local Display Unit (LDU200) to a room-level network:
  - Displays data from any valve controller on the room-level network on a 2.1-inch square liquid crystal display (LCD) panel
  - Up to 250 parameters may be mapped to a LDU; each display shows a description and present value for up to 5 parameters
  - Passcode protected to prevent unauthorized set point changes

- To create custom control sequences, add a Programmable Control Module (PCM) to a room-level network to implement complex, non-standard control sequences through a BASIC-like programming language:
  - Provides assorted inputs and outputs (quantity varies by model number)
  - Provides local trending and scheduling functions
- To integrate the Celeris Environmental Control System with the BMS:
  - Add routers and repeaters, as required, to create a building-level communications network for all of the Celeris room-level control networks
  - Add a LonTalk network to the BACnet interface to connect up to 2,000 devices to the BMS through one portal

Each device on the network reports its status and relays data associated with the room-level control functions it carries out to the BMS for integration purposes.

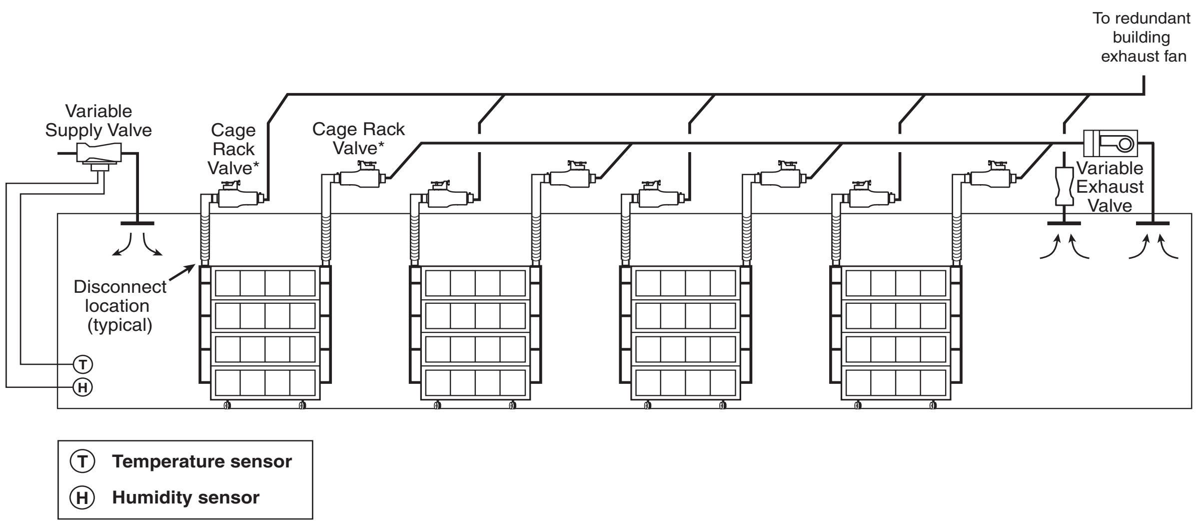


Figure 4-8. VAV for rodent holding rooms-air valve operation. *Thermal or ventilation requirements command the supply valve to the required flow, while the room's general exhaust valve adjusts to maintain room pressurization. Ventilated racks are maintained at a constant volume.*

Pressure Control in High-level Containment Labs

High-level containment spaces are typically pharmaceutical manufacturing cleanrooms or spaces classified as biosafety level 3 (BSL-3) or higher, which may include vivariums and specialized labs. Pressurization control generally requires a relatively tightly sealed space; however, some leakage is required to provide some level of offset flow.

To satisfy certification agency and validation requirements in these high-level containment labs, Phoenix Controls added the Progressive Offset Control (POC) differential pressure control feature to its Celeris Environmental Control System. This POC function is built on the fundamental basis of a volumetric offset control function with a differential pressure control algorithm to trim the offset to maintain the desired differential pressure.

Spaces controlled with the POC function generally exhibit superior performance over conventional pressure control schemes relative to:

- Closeness of control
- Responsiveness to changes in switched or variable airflow control devices
- Recovery from a disturbance, such as a door opening or closing

The superior performance of the POC function is attributed to the Celeris high-speed volumetric offset control function, which controls gross changes in airflow, and includes:

- Base ventilation demand (air changes)
- Base pressurization levels
- Thermal override for cooling or heating demand
- Monitoring flow feedback of non-networked switched or variable flow devices, such as biosafety cabinets and dust collectors, and responding to changes in flow

The subtle tuning in pressurization control is handled through an independent control loop layered over the top of the volumetric offset control function. A relatively small percentage of the total flow control range is reserved for pressurization control.

- This provides greater accuracy and resolution because the pressure control loop is operating over a small percentage of total flow.
- Even with the pressure control loop disabled, there is still volumetric offset and directional airflow control.

The POC function responds quickly to maintain directional airflow when a door to the pressurized space opens and recovers quickly once the door closes. Because it is not practical to maintain space pressurization across an open door, door switches are used to detect the opening or closing of doors to adjoining spaces. This method allows the system to:

- Freeze the pressure control loop to prevent it from winding up
- Freeze the pressure control output at the last value
- Change the offset to a higher value while the door is open to increase the directional airflow, which prevents space contamination

Differential pressure control schemes require significantly more effort to commission and maintain than straight volumetric offset. Some considerations:

- Use airlocks and anterooms to segregate pressurized spaces from non-pressurized spaces.
- Openings or passageways between pressurized spaces should be only one step above or below the adjacent space.
- Map out personnel and material flow carefully to prevent cross-contamination.
- Place pressure sensor ports where they will not be influenced by stray air currents.
- It is sometimes best to connect the reference port to a large bore (one-half to one-inch) pipe or tube to serve as a dampener for fluctuations on the reference port.

Phoenix Controls Shut-off Valves

Phoenix Controls Shut-off Valves are available in two valve designs—Standard (Option S) and Low-leakage (Option L). Both designs are intended for use in critical airflow applications, where isolating the HVAC system from the room is necessary.

The Shut-off Valve provides critical airflow control demanded by a modern research facility. In shut-off mode, the valve provides low-leakage isolation of the HVAC system from the room.

An example of a typical application is a laboratory research building space using gaseous biodecontamination.

- The shut-off sequence can be initiated either locally through a universal input or remotely via the network—either from the building management system (BMS) or Local Display Unit (LDU).
- The valve can function as a standalone device or as part of a fully integrated system.
- Precise airflow control—The factory-calibrated flow rate controller performs accurately throughout its operating range.
- Self-balancing pressure-independent operation—The valve maintains the airflow set point by automatically compensating for static pressure fluctuations in the system.

Low-leakage Shut-off Valve

The Low-leakage Shut-off Valve accommodates applications requiring a near bubble-tight ventilation system for critical environments needing emergency isolation or gaseous biodecontamination.

Many project standards for applications, such as BSL-3 spaces, may require a higher standard of isolation than what the Standard Shut-off Valve provides. With the Low-leakage Shut-off Valve, leakage rates achieved are insignificant to the overall duct volume.

In many projects, the duct volume entering and exiting critical spaces must be leak tested to ensure they are truly isolated. Most governing standards accept leakage rate from 0.1–0.2% of volume per minute of the duct volume at a given pressure. The Low-leakage Shut-off Valve contributes minimally to the overall volume tested. This insignificant leakage volume, combined with the valve's ability to control airflow precisely and compensate instantly to changes in pressure, makes the Low-leakage Shut-off Valve the ideal choice for these critical applications.

The Low-leakage Shut-off Valve, which has been tested with the ASME N510 Pressure Decay method,[1] has the lowest total casing leakage compared to our current valve portfolio. The casing leakage for this valve is 0.01 CFM per square foot for each area.

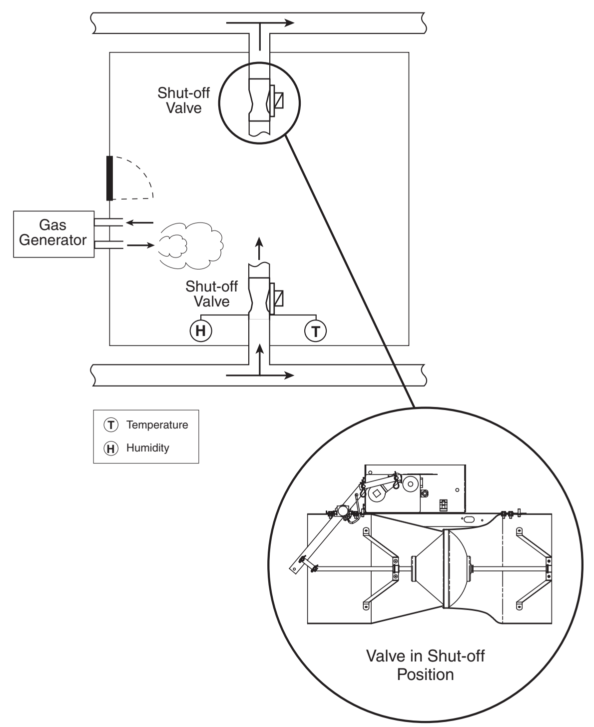


Figure 4-9. The typical room setup for decontamination.

During the decontamination cycle:

- The space is taken from a normal control mode to a depressurization mode where the airflow is reduced to minimum flow while remaining slightly negative. Equipment that will not be decontaminated is moved out, then the decontamination equipment is set up.
- The space is switched to a shut-off mode where the supply and exhaust ducts are effectively closed off (see leakage table below) and the door is sealed.
- The decontamination process commences and runs for the prescribed duration.
- The space is set back to the depressurize mode (slightly negative) and the door is unsealed.

[1] American Society of Mechanical Engineers (ASME), ASME N510, Testing of Nuclear Air Treatment Systems, 1985 (reaffirmed 1995).

Control Applications

- The space is set to purge mode, where the valves open to their maximum set value while maintaining negative pressurization until the decontamination agent is purged.
- The room returns to normal operational control.

The entire HVAC control sequence can be completed by using network commands locally with a Local Display Unit (LDU) or remotely via the BMS.

Calculating Valve Area

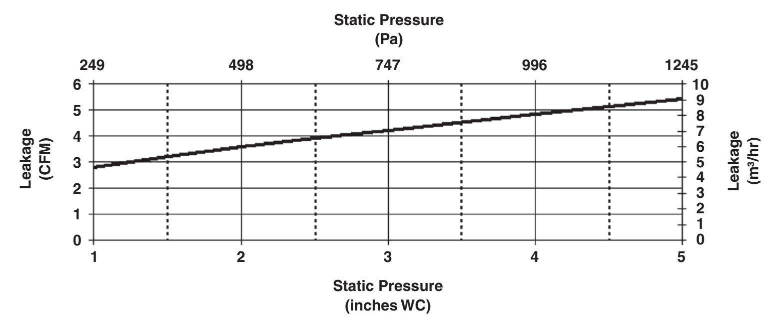
Use the valve area to convert casing leakage per square area to a standard leakage rate (CFM and l/sec). See the tables below.

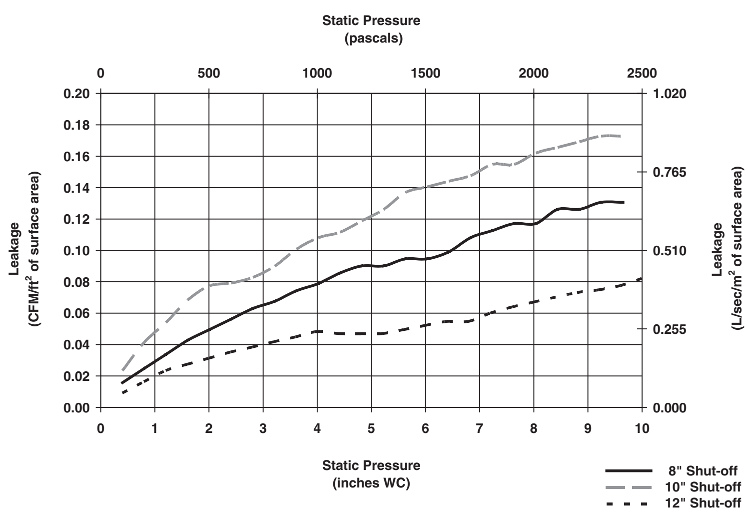
Valve Areas		
Valve Size	Area (ft^2)	Area (m^2)
8"	3.60	0.33
10"	4.26	0.40
12"	6.28	0.58

Recommended Valve Class for Decontamination Agents	
Gaseous Decontamination Agent	Recommended Valve Class*
Hydrogen peroxide vapor	Class A
Ethylene oxide	Class B
Ammoniumchloride	Class A
Chlorine dioxide	Class A**
Paraformadehyde	Class A

** Chemical resistance data acquired from Compass Corrosion Guide.*
*** For concentrations up to 800 ppm. To achieve higher concentrations during decontamination, use Class B valves.*

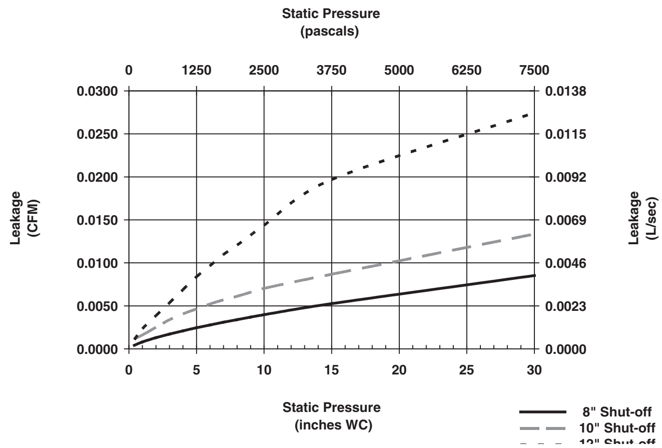
Figure 4-10. Leakage for the standard Shut-off Valve, Option S. *The shut-off leakage is shown in the top graph, and the casing leakage is displayed in the bottom graph.*

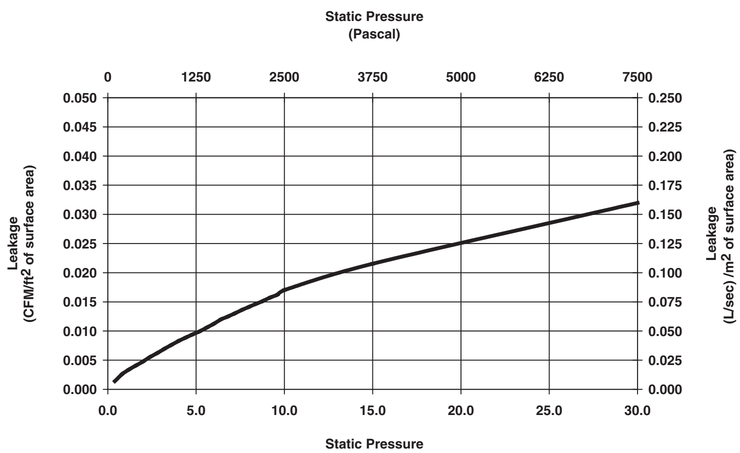




NOTE: To covert these values to standard leakage (CFM), see the "Calculating Valve Area" sidebar above.

Figure 4-11. Leakage for the standard Shut-off Valve, Option L. *The shut-off leakage is shown in the top graph, and the casing leakage is displayed in the bottom graph.*





NOTES:

- *Exceeds Eurovent Class A, B, C and D specifications (Eurovent Committee of Air Handling and Equipment Manufacturers).*
- *To covert these values to standard leakage (CFM), see the "Calculating Valve Area" sidebar on page 48.*

Configurable Inputs and Outputs (I/Os)

The Celeris Environmental Control System and Traccel Room Controller accommodates a wide variety of input and output (I/O) devices that implement room-level control schemes (see table below).

Type of Input or Output	Number Available		Devices Accommodated
	Celeris Environmental Control System	Traccel Room Controller	
Universal input (UI)	3	3*	From voltage, current or resistance sensing devices. • 0 to 10 Vdc • 4 to 20 mA • 0 to 65,000 ohms • Type 2 or 3, 10 kohm thermistor temperature sensor
Digital input (DI)	1	1	From two-state input or alarm devices, such as occupancy sensors or override buttons, key switches, or alarm circuits • Dry contact • Logic level voltage input
Analog output (AO)	2	2	Drives voltage or current-driven actuator devices, or provides a physical signal representing flow feedback or set point values • 0 to 10 Vdc • 4 to 20 mA
Digital output (DO)	1	1	Used for two-state control functions, local alarm annunciation or offset status • Single-pole, double-throw (Form C) relay rated 1 A @ up to 30 Vac/Vdc • Configurable for direct or reverse acting
Triac 3 output	N/A	1	Used for floating point control of reheat actuators
** 5 with the TX option*			

With the Celeris Environmental Control System, a sensor, switch or transmitter may be connected to any available input on any available valve controller and passed across the network for control, monitoring and integration. Once connected, it can be scaled, defined as one of the 28 different data types supported by the Celeris system, and passed to any other valve controller for control purposes or to a data server for integration. Such convenience of passing data across the room-level network leads to substantial savings in wiring, resulting in a less complicated network. Examples of where this may apply include:

- Non-networked flow devices may be connected to the input of any valve controller and the flow term may be factored into the zone balance equation
- Room-level devices with voltage or current outputs or alarm contacts may be connected to any valve controller input. The analog value or alarm state will be passed across the Celeris network to the BMS

Any available analog and digital output on any Celeris Valve Controller may be configured to be under the BMS' control. The physical output may be scaled and configured for direct or reverse acting and associated with a network variable to which the BMS can freely write a value. The value or state will be saved in the valve controller's non-volatile memory so that the command is retained over a power cycle. Examples include:

- The BMS must set an analog set point for a non-networked room-level control device
- The BMS must send a start or stop command to a non-networked room-level device

The room-level network may be used in lieu of hard-wired connections to:

- Fan out the reheat command signal to multiple supply valves with reheat coils
- Simplify wiring by allowing you to connect a sensor to a valve controller that is either more convenient or has an input available to pass the variable across the network to the valve implementing the control function

Because the Traccel Room Controller is typically used for more basic control applications, sensors and actuators terminate directly on the controller. Non-networked device support is somewhat limited.

Room-level Applications

The Celeris Control System and Traccel Room Controller implements a wide variety of room-level control schemes. It also accomplishes many sophisticated control sequences simply by connecting sensors and actuators to any available input or output on any available valve controller and configuring the modular control functions. The valve controllers use the room-level network to share I/O and control data to execute the desired control sequences.

The Traccel Room Controller offers a more economical solution with built-in input output (I/O) and all available control functions carried out by the single controller.

	Celeris	Traccel TP	Traccel TX	Traccel SO
Zone Balance Control				
• Ventilation demand (ACH)	x	x	x	x
• Volumetric offset control	x	x	x	
• Control airflow distribution across multiple supply valves	x			
• Differential pressure control	x			
• Makeup air control for fume hoods	x			
• Monitor non-networked device airflow; incorporate in zone balance function	x	x	x	x
Temperature Control				
• Control reheat actuator	x	x	x	x
• Control ventilation rate for cooling or heating control	x	x	x	x
• Dual duct control (hot duct/cold duct)	x			
• Thermal anticipatory control	x			
• BTU compensation	x			
• Auxiliary temperature control loops (cooling or heating, standalone or staged)	x	x	x	x
• Multiple temperature zones per lab (quantity)	x (4)	x (3)*	x (3)*	x (3)*
Humidity Control				
• Humidification actuator control	x		x	
• Dehumidification actuator control	x		x	
Occupancy Control				
• Reset minimum ventilation for occupied and unoccupied periods	x	x	x	x
• Reset temperature control set points for occupied and unoccupied periods	x	x	x	x
HVAC Control Modes				
• Predefined purge, decontamination and shut-off modes	x		x	
• User configurable modes for decommission, supply fan or exhaust fan failure, etc.	x	x	x	x
**Temperature zones share common exhausts*				

Each controller is assigned specific room-level control functions. Each valve controller is defined as either a supply or exhaust valve and then assigned some combination of room-level control functions, such as zone balance, temperature, occupancy, emergency mode, humidity or fume hood control. Sensors and actuators are connected, control functions are configured, network connections are defined and the system is then ready for use.

Monitoring Animal Facilities

A well-monitored system is not necessarily a well-controlled system.

Monitoring Requirements

"Regular monitoring of the HVAC system is important and is best done at the individual-room level (ILAR, p. 75)."

AAALAC accreditation typically requires a record of:

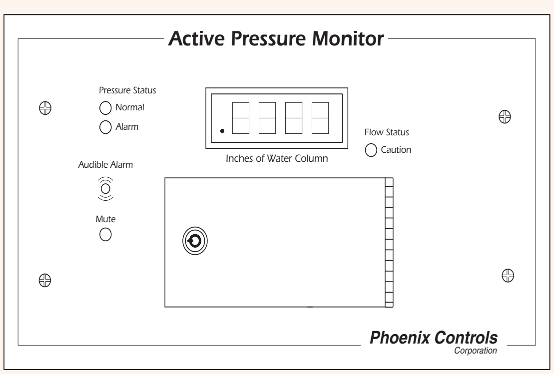
- Room temperature
- Room relative humidity
- Room pressurization
- Supply system flow
- Exhaust system flow

Less frequently, room air change rates are also monitored continuously. Ongoing record keeping of these parameters is also commonly done, especially as federal regulations require it, or when AAALAC accreditation is a goal of the facility.* The Program Status Evaluation (PSE) is the document used in the assessment of a program and is described at the following Web address: http://www.aaalac.org.

It is not uncommon for the HVAC system to be the final punch list item in obtaining AAALAC accreditation. This is due to the stringent testing the system undergoes during evaluation to prove that it is capable of maintaining the stability required to support research that can potentially span multiple years.

Vivarium Monitoring Systems

The use of the BMS to monitor laboratory animal facilities has not been universally accepted since monitoring and control is usually done remotely, perhaps central to a campus, away from the animal facility. This does not allow animal facility personnel the flexibility, control and assurance they often require or desire. This situation has opened the door for environmental monitoring systems dedicated to the vivarium.



Integrating Monitoring and Control Systems

Data collection and reporting can be done in several ways:

1. *Dedicated vivarium environmental monitoring systems* (examples: Edstrom Industries, Rees Scientific)

   These systems are in addition to BMS systems and offer animal facility personnel their own monitoring system that reports data to their desktops, rather than through the BMS front end.

2. *Building Management Systems (BMS)* (examples: Andover Controls, Automated Logic, Honeywell, Johnson Controls, Siebe, Siemens)

Phoenix Controls has established partnerships with all of the above BMS contractors for digital integration for control and monitoring. Analog interface is available for integration with all of the companies listed above.

Monitoring Sensors/Devices

Temperature: Typically located in ducts and/or on the walls of rooms.

Humidity: Usually located in the room's general exhaust duct and/or in the room.

Light: Strategically located.

Airflow: Duct-mounted or flow feedback signal from a Phoenix Controls valve.

Pressure: The pressure monitoring device indicates alarms and/or actual pressure differential. These devices may also include functionality to switch rooms between positive and negative pressure.

* Airflow monitoring for AAALAC accreditation can have numerous meanings. For example, duct flow measuring stations, airflow control valve feedback signals or even periodic flow hood data can all meet AAALAC requirements.

Integrating Laboratory Airflow Control Systems

An integrated laboratory airflow control system offers all of the benefits that our standalone system provides:

- Maximum safety
- Reduced first costs
- Decreased operating costs
- Reliability
- Flexibility

While these benefits continue to be the foundation of our offering, integrating the laboratory controls with the BMS makes it easy to monitor the status of the fume hoods from a central location and archive operating data. System integration expands and improves upon the core benefits by providing:

- Comprehensive remote monitoring and diagnostics
- Sash management monitoring
- Energy use tracking
- Easy identification of potential operating problems
- Report generation through the BMS, such as alarm monitoring, safety analysis and energy use

Phoenix Controls offers integration through a variety of product lines:

- Celeris Environmental Control System (digital)
- Traccel Room Controller
- Analog devices

Collecting and exchanging data between devices that make up the building controls system are the key elements in turning front-end systems into building automation systems (BASs) or building management systems (BMSs). Controls systems in today's buildings are becoming increasingly sophisticated, relying heavily on microprocessor-based controllers to implement the desired control strategies. With the advent of plant, floor and room controllers powered by high-end microprocessors, the question becomes, "How do you knit all of this into one homogeneous system?"

In the past, many BASs relied primarily on proprietary protocols to establish communications between field devices and the front-end. This effectively locked competitors out of buildings or campuses because there was no practical way for control equipment from one vendor to communicate with the BAS of another vendor. Owners demanded interoperability, and the industry responded by defining and documenting open communication schemes like BACnet (Building Automation and Control network) and LonTalk (local operating network).

BACnet

The BACnet Committee was formed in 1987 and began work on the BACnet standard. In June 1995, after years of industry input and reviews, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) adopted BACnet as a new standard for the industry. In 2003, the International Standards Organization (ISO) and European Committee for Standardization (CEN) adopted BACnet as a European standard (EN ISO 16484-5). BACnet has undergone several major revisions; the current version is Standard

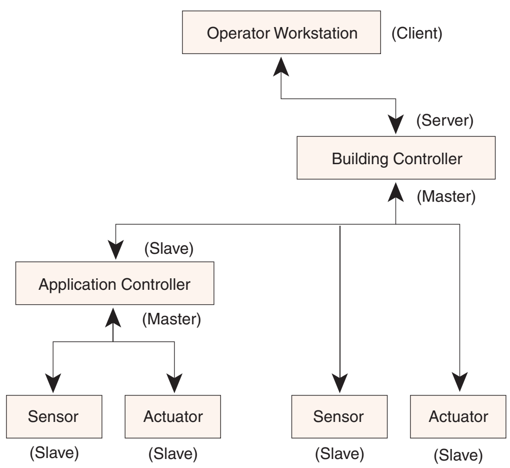


Figure 4-12. BACnet architecture.

135-2004. There are several BACnet Interest Groups (BIGs) that have formed around the world to promote the use of BACnet, as well as the BACnet Testing Laboratory (BTL), which tests products to certify compliance with the BACnet standard. There are currently 75 known manufacturers of BACnet products.

BACnet is based on a model where devices and their associated *points* are represented as *objects*: device, analog input, analog output, binary input, binary output, and so on. These objects have a varying number of properties, such as present value, object name, object ID, description, status, etc. These object properties are passed from one device to another through *services*, such as read property, write property, change of value, and event notification, to name a few.

The BACnet architecture is based on an established hierarchy of a client/server or master/slave relationship between devices. Clients (masters) make requests of servers (slave) devices, and the server (slave) devices respond. There are defined methodologies for how a client (master) device can query a server (slave) device to determine which objects and services the server (slave) device supports in order to establish communications with that device. Data may be retrieved using various polling mechanisms (read property, read property multiple) or by the client subscribing to a server's data sharing service (change of value, etc.).

The BACnet standard defines these device types:

- Operator workstation–This is the human-to-machine interface device or terminal where data is captured and displayed. It may be used to configure devices and systems, but it is not intended to implement control strategies.
- Building controller–This is a general purpose, field programmable device that executes many of the control and automation routines as part of the overall building control strategy. A building controller is typically a floor-level or supervisory controller with a fairly high level of integration that can act as a router (or bridge) between the building-level and floor-level network segments.
- Advanced application controller–This class of controller fits between the higher-end building controller and less sophisticated application specific controller.
- Application specific controller–This class of devices has limited programmable control capabilities and resources relative to the advanced application controller. It is generally intended to perform specific types of control or automation functions.
- Smart actuator–This type of device is typically a simple control device with limited resources intended to perform a specific function.
- Smart sensor–This is a simple device with very limited resources intended for simple sensing and detection applications. It also defines the minimum subset of BACnet functionality or services each class of device must support. These services are known as *BACnet Interoperability Building Blocks (BIBBs)*, which are organized as follows:
  - Data sharing–These services define how messages are formatted and passed between devices using services, such as read property, read property multiple, write property, write property multiple and change of value.
  - Alarm and event management–These services define how alarm messages are structured, delivered and acknowledged.

- Scheduling–These services define how events scheduled by dates and times are administered between devices on the network.
- Trending–These services define how trend log files are structured, how devices on the network can initiate or end trend sessions manually and programmatically, and how the files are passed between devices.
- Device and network management–These services define how one device on the network can initiate communications with one or more other devices, how it can programatically discover which functions the device(s) support, and which device and point objects are available. There are several network management functions, such as restarting or reinitializing a foreign device.

There are typically at least two layers for a BACnet network:

- Building-level network–This network generally consists of BACnet workstations and data servers communicating with various BACnet controllers. The communication method is typically through a client/server relationship using BACnet over Ethernet or Internet Protocol (IP), depending upon the facility's network architecture.
- Floor-level network–This network typically contains BACnet controllers communicating with lower-level controllers that communicate with smart sensors and actuators. The communication method often employed is a BACnet master slave/token passing (MS/TP) network using EIA-485 or point-to-point with RS-232.

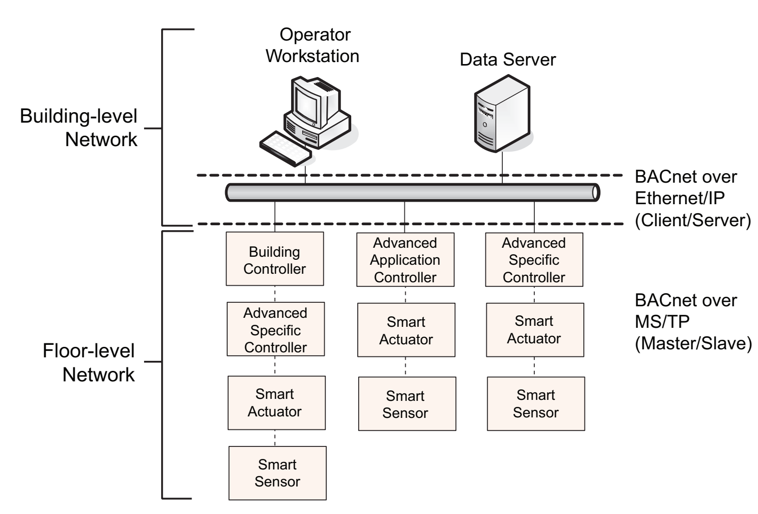


Figure 4-13. Layers of a BACnet network.

BACnet uses sophisticated schemes for one device detecting other devices and reading which services are supported, which objects are available, and the properties of the device's input and output objects. These methods are defined for establishing communications between devices:

- Read/write property, a single read and write request sent from one device to another to update the value or status of a device or point object property. This mechanism relies on a poll/response communications scheme.
- Read Property Multiple/Write Property Multiple–A complex read and write request sent from one device to another to update the value or status of a multiple properties of a device or point object. This mechanism relies on a more sophisticated poll/response communications scheme.
- Subscription based services–These schemes rely on one device subscribing to a change of value or event notification service of another device. Using these schemes the subscriber requests data updates be pushed from the sender to the recipient based on an object property changing value or state. These schemes offer tremendous network efficiencies as only dynamic values are passed.

In general, the BACnet protocol is very feature rich in that there is a lot of information available from each device and for each point available from that device. BACnet is intended to be a hierarchal type of architecture and is very well suited for handling large volumes of data over large scale networks.

LonTalk

The LonTalk protocol was developed by Echelon Corporation in the early 1990s. The protocol is incorporated in several standards ANSI/EIA709.1, SEMI E56.6, IEEE 1493-L, EN14908, and others. The Echelon transceiver technology has been approved under ANSI/EIA709.2 and 709.3 and is expected to be included in the EN14908 standard. There are numerous branches of LonMark International around the world. LonMark promotes the use of LonWorks technology and maintains the standard as well as certifies products meet the standard for interoperability. There are currently 228 members of LonMark International. There is also an organization called the Open Systems Alliance (OSA) which is a pool of systems integrators and companies that train them to design, install, and commission LonWorks systems. There are currently 187 member organizations.

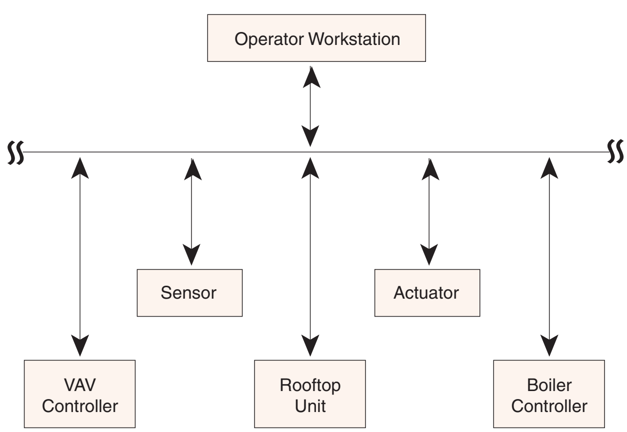


Figure 4-14. Peer devices on a LonWorks network.

LonTalk is a much more simplistic communications protocol than BACnet. The LonTalk protocol was designed around the principle of a peer-to-peer network where any device on the network can share data with any other device on the network. The functionality of the device is defined, the structure of the network variables, and the protocol is embedded in the application microprocessor. Interoperability on a LonWorks network is tied to two key elements established by LonMark International:

- Functional profiles–The concept of the functional profile is that most control devices will fit into some generic classification where the basic functionality and input and output points required for control and integration can be defined. There are currently 86 functional profiles defined by the LonMark organization which outline the general functionality of everything from a temperature sensor to a roof-top unit controller. This allows systems integrators to know what functionality they can expect from a device and what input and output network variables will be available to integrate with other devices or with the BMS.
- Data types–Points or network variables in the LonWorks world are defined as standard network variable types (SNVT). The LonMark organization has at present established 187 standard network variable types for everything from a simple voltage value to the operational status of a piece of HVAC equipment. Each SNVT is thoroughly defined in terms of range, resolution, polarity and for enumerations the function of each state is defined. This allows them to be passed across the network and shared with other devices through simple read and write commands. If device A is reading a temperature value from device B, the fact that it is a LonMark defined SNVT means that each device knows exactly what to expect in terms of range, resolution and format.

Therefore, a temperature sensor or space comfort controller from one vendor will have a minimum subset of input and output network variables identical to devices with the same profile from other vendors. Each device has an external interface file (XIF), which defines the functional profiles and resulting network variables supported by each product. Therefore, the systems integrators can anticipate what variables will be available from a device and in which format these will be.

Because devices on a LonWorks network are all peers, the network is essentially flat, even though there may be some hierarchal structure built in to the network topology in order to manage network traffic or wiring considerations. Because of the flat architecture, data may be passed easily from one device to another. As with BACnet, data can be passed either through a poll/response or broadcast scheme where one device will "push" its data to other devices by way of a change of value or heartbeat scheme. Because each interoperable device on the network understands the supported data types, the messages passed between devices tend to be small and extremely efficient. Most devices on a LonWorks network rely on a COV or heartbeat scheme, or binding, which allows device-to-device communications to be very efficient.

Interoperability

Many BAS vendors have responded by supporting both the BACnet and LonTalk protocols, at the room-level, floor-level and enterprise-level. This opened the door for many smaller companies to develop sensors, actuators and controllers that are highly interoperable with the majority of building automation systems on the market.

BACnet and LonTalk have been implemented in every type of device from wall switches to Internet-based, multi-building, data management systems. To ensure interoperability, organizations, such as the BACnet Testing Laboratory and LonMark International, established guidelines and testing protocols to determine the interoperability of products. This gives owners and engineers many choices when selecting equipment to be used in their buildings–whether it is based on price, features, quality, or brand loyalty.

One of the most important features of the Celeris system is its ability to seamlessly integrate thousands of points from hundreds of lab spaces through a single connection to the BAS. Fume hood data, flow data, and comfort control data, along with miscellaneous points picked up through hard-wired connections in the lab are made available to the BAS system for trending, scheduling, alarming and display on operator workstations.

While Phoenix Controls believes LonWorks is an excellent communications protocol for peer-to-peer control architecture, we also believe that BACnet is better suited to manage large numbers of devices and points in a consistent manner.

Phoenix Controls offers two networked-based control platforms:

- Celeris Environmental Control System–Uses the LonWorks room-level network to implement a peer-to-peer control architecture, connected to a LonTalk to BACnet data server which is used to integrate the Celeris system with BACnet capable BASs. The Celeris system offers the utmost in flexibility, scalability, and sophistication to implement complex control sequences.
- Traccel Room Controller–Uses LonWorks technology incorporated into a valve mounted room controller to integrate flow and temperature data directly onto the BAS vendors LonWorks bus. The Traccel room controller is LonMark certified as a Space Comfort Controller, Variable Air Volume (SCCVAV Object type 8502. The Traccel system provides ventilation, pressurization and comfort control for non-fume hood lab spaces. Traccel controllers may also be integrated through use of one of the Celeris LonTalk to BACnet data servers.

Phoenix Solutions for Integration

Integration Solution #1: Celeris Environmental Control System

The Celeris Environmental Control System is designed around the concept that each pressurized space operates as an independent, local control network. These local control networks may be connected to create a floor-level or building-level communications network, which ultimately connects to the enterprise-wide network and the BAS using either the MicroServer or MacroServer LonTalk to BACnet data servers.

- The MacroServer is intended for large scale integration supporting up to 6,000 BACnet objects, or approximately 1200 devices.
- The MicroServer is intended for small to medium scale integration supporting up to 350 BACnet objects, or 35 devices.

There may be multiple MacroServers or MicroServers on the BACnet network and they be mixed, as required, to integrate the systems.

The MacroServer and the MicroServer include utilities to discover devices on the Celeris network and to map the desired points to BACnet objects. Each device on the Celeris network uses a combination of a Change of Value and a heartbeat scheme to "push" the present value for each network variable to the data server. This allows the most efficient use of network bandwidth and ensures the present value in the data server accurately reflects data in the field device. The data servers convert the LON data to BACnet objects and makes the data available to the BAS through its BACnet data sharing and alarm and event management services.

The MacroServer and the MicroServer support the full complement of BACnet services that allow the BAS to automatically discover the devices and the objects and services supported. At the room level, the CVCs pass data back and forth among each other to implement room-level control schemes. Control data is restricted to the room-level network by a LonWorks router.

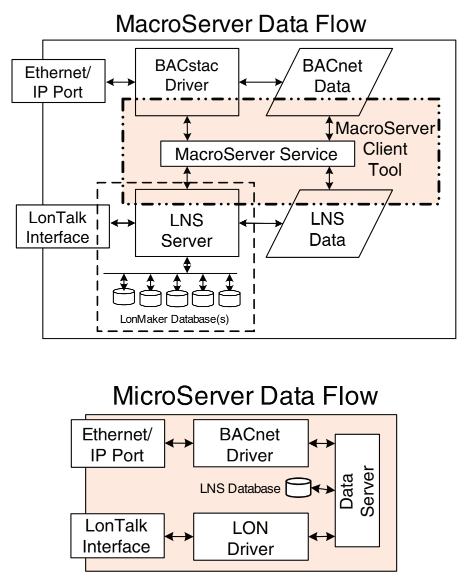


Figure 4-15. Data flow from and to MacroServers and MicroServers.

Each valve controller is also responsible for passing data to one of the Celeris data servers using custom user-defined network variable types (UNVTs). The UNVTs used by the CVC consist of multiple SNVTs, relative to a specific control function, packed into one large network message variable. This provides tremendous optimization of network bandwidth and allows the Celeris Environmental Control System to extend well beyond the typical size and density of a typical LonWorks network.

The data servers collect data from the floor- or building-level networks, and convert the LonWorks data into BACnet objects. The servers create a seamless virtual network of BACnet

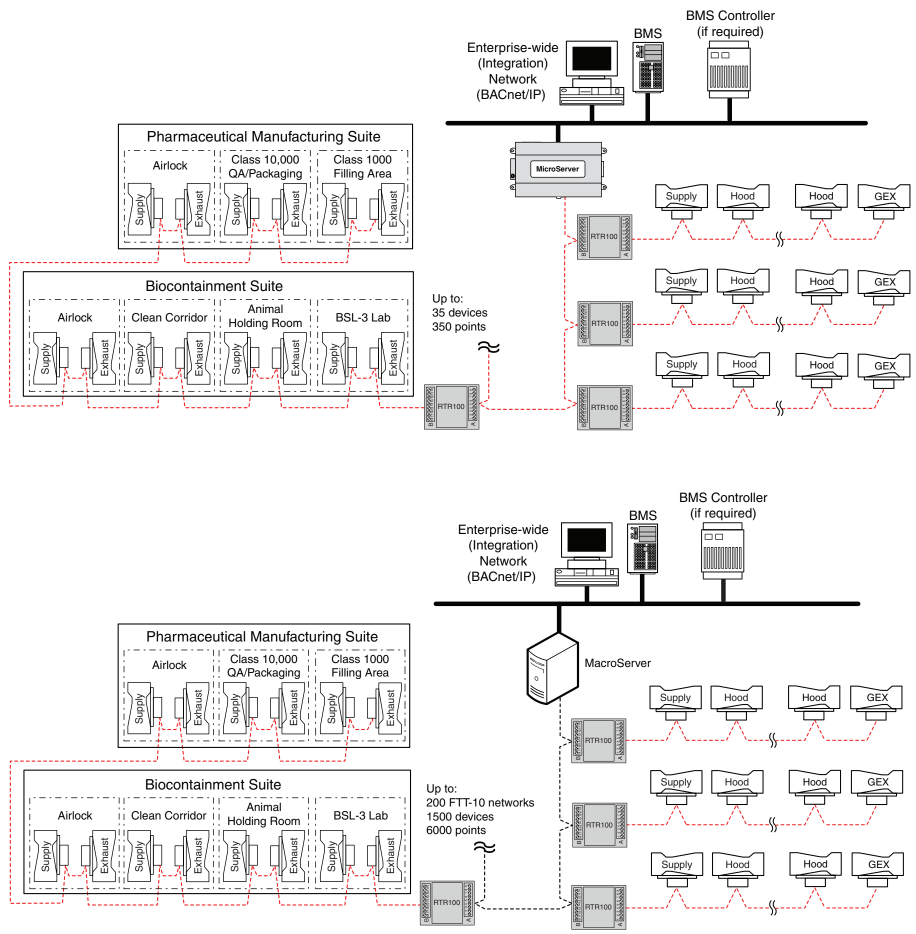


Figure 4-16. BACnet network layouts incorporating Celeris products for building managment system (BMS and building automation system (BAS).

devices and objects, and make the data available to the BAS through a variety of BACnet data sharing and alarm and event notification services. The data servers collect data from the floor- or building-level networks, and convert the LonWorks data into BACnet objects. The servers create a seamless virtual network of BACnet devices and objects, and make the data available to the BAS through a variety of BACnet data sharing and alarm and event notification services.

In the Celeris Environmental Control System, there are three network levels:

- Control network–This is the room-level network where all the devices reside and device-to-device communications is used to implement the desired room-level control strategy. The network uses the LonWorks 78 kbps FTT-10 communications scheme and is generally a single channel with a router at the top end of the network to connect it to the communications network.
- Communications network–This is the floor- or building-level network where all the network interface devices reside. The purpose of the communications network is to connect all the room-level networks together via routers to establish a data path from nodes on the room-level network to the MicroServer or MacroServer for integration to the BMS. The communications network may either be a floor- or building-level network.

- Floor-level network–This communications network uses the same 78 kbps FTT-10 communications scheme as the room-level control network. This style network is used with the MicroServer and RTR200 series routers. The floor-level network has a maximum distance of 4,500’ (1,400 m), which is more than adequate for the number of devices supported by a single MicroServer. Repeaters are generally not required and are not supported.
- Building level network–This is a high-speed network (1.25 mbps) using the LonWorks TP-1250 communications schemes. The style network is used with the Phoenix Controls MacroServer and RTR104 and RTR100 series routers. The TP-1250 network has a maximum distance of 425’ (130 m); however, it may be extended by adding a repeater (RPT100).

- Integration network–This is the network used by the Phoenix Controls MicroServer or MacroServer to interface with the Building Management System (BMS). It is typically the campus or corporate intranet, however it could also be a dedicate network for the building controls system. The MicroServer or MacroServer use the BACnet protocol over either Ethernet or IP to exchange data between the Celeris system and the BMS controllers and operator workstations.

Grouping devices into logical subnets ensures that there is sufficient network bandwidth to carry out room-level control strategies. The type of control application desired determines the number of nodes that may make up a subnet.

For laboratory spaces where make-up air control for hoods and one-second speed of response is required, there are one router per pressurization zone and a maximum of 20 nodes for each zone. For tracking pair applications where speed of response is not critical, there may be up to 32 nodes per router and multiple pressurization zones for each router.

Routers

Routers isolate communications on the room-level network or channel from communications on the building-level network or channel. Routers monitor communications on both channels and will only pass messages from one channel to the other if the message is specifically addressed to cross the router. Messages on the room-level network will be passed only to the floor or building-level network if these are “bound” to a device on that network, or to a device on another room-level network. An example is room-level data that is being passed to the MicroServer or MacroServer for integration to the BAS. Similarly, messages on the building-level network will only be passed to the room-level network if these are specifically addressed to a node on that channel.

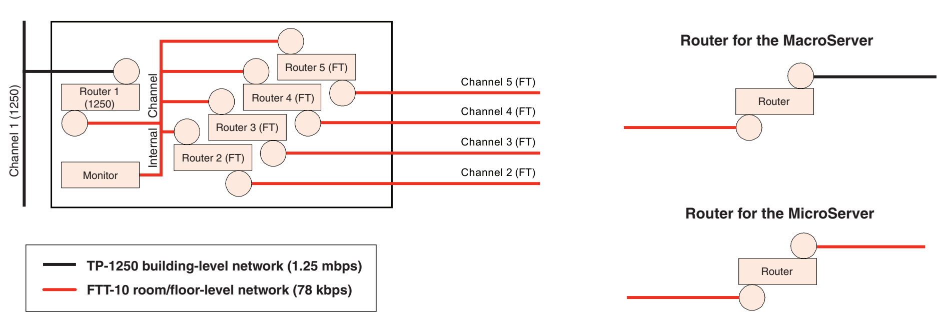


Figure 4-17. Routers for the MacroServer and MicroServer.

Repeaters are used only on projects using a MacroServer. These are building-level network devices, specifically intended to increase the distance data can travel on the 1.25 mbps building-level network. Each TP-1250 building-level network segment is limited to 425 feet of cable. If the building-level network must extend beyond 425 feet, a RPT100 would be used to boost or retransmit the communications signal, which extends the network an additional 425 feet. Any message received on the A channel is passed to the B channel immediately. You can use as many RPT100s as necessary on the building-level network.

Network Layouts

- Each room-level control network is wired in a bus topology and requires two FTT-10 end-of-line terminators, which are included with routers purchased from Phoenix Controls.
- The floor-level communications network is wired in a bus topology and requires two FTT-10 end-of-line terminators, which are included with each MicroServer purchased from Phoenix Controls.
- Each segment of the building-level communications network is wired in a bus topology and requires two TP-1250 end-of-line terminators, which are included with each repeater and MacroServer purchased from Phoenix Controls.
- The enterprise integration network follows the architecture laid out by the information technology (IT) professionals involved with the project. All that is required for Phoenix Controls to connect the MicroServer or MacroServer to this network is a 10 base T, 100 base Tx or 1000 base Tx connection.

Because the Celeris MacroServer and MicroServer function as a BACnet server and support BACnet over IP, Celeris systems in multiple buildings and on multiple campuses can be integrated on one wide area network (WAN). Because the BAS is simply a BACnet client requesting data or subscribing to the data services of the Celeris system, multiple clients from multiple BAS vendors can retrieve data seamlessly.

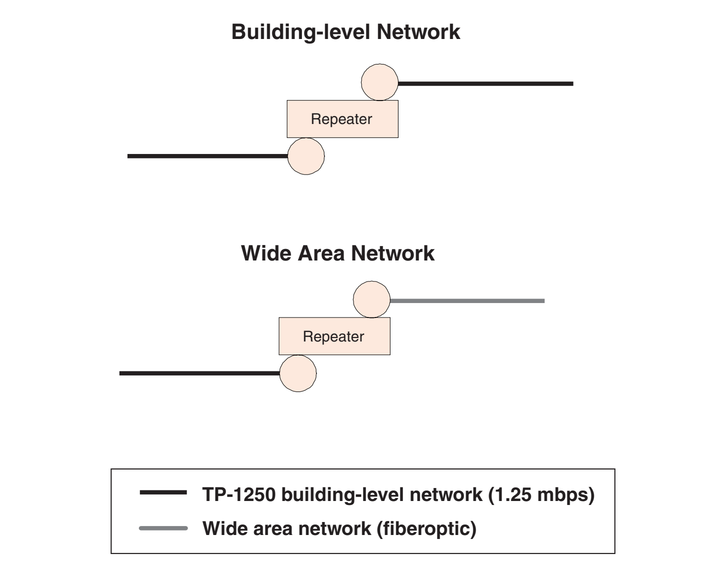


Figure 4-18. Repeaters in building-level and wide area networks.

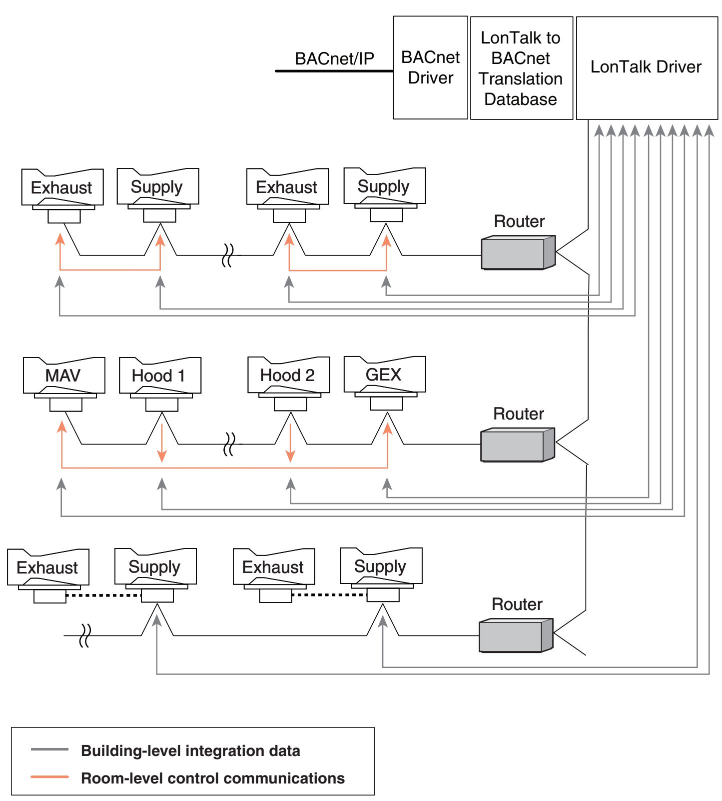


Figure 4-19. An enterprise integration network.

MicroServer™ and MacroServer™

The Celeris Environmental Control System provides a simple, efficient means of integration. While LonTalk is an excellent protocol for peer-to-peer distributed control functions, we have found BACnet to be a more widely accepted BMS integration protocol. The Celeris system includes scalable integrations solutions, such as the MicroServer™ and MacroServer™.

- MicroServer–Use one or more of these devices for small- to medium-sized systems (less than 175 nodes) or integrating laboratories in remote or isolated sections of the building.
- MacroServer–One MacroServer has the capacity for medium- to large-scale systems (150-1200 nodes).

These data servers collect data from all the room-level devices and expose it to the BMS by using the BACnet protocol for read and write access. These data servers carry out several critical functions in creating an interoperable network. These functions are listed below.

- The data servers are integration tools that create a virtual network of BACnet devices, objects and services.
  - These function as servers to the BACnet network, allowing any BACnet client to request data and/or command set points.
  - Points mapped for integration are converted from LonTalk data to BACnet objects.
  - Data from the room-level devices are pushed to the data servers, where the information is stored and made available to the BMS.
  - These servers convert BACnet commands from the BMS to LonTalk messages, route these messages to the appropriate CVC and acknowledge each successful command.
  - These servers manage alarm data to ensure that the BMS receives every alarm message generated by a room-level device, typically in less than 2 seconds.
- The data servers are network management tools.
  - These servers may connect directly to the building's LAN and communicate with other BACnet devices using Ethernet and/or TCP/IP at either 10 or 100 mbps.
  - These servers act as servers to BMS clients.
  - All network configuration and service tools are available.
  - These servers route messages from the BMS to the appropriate CVC.
  - These servers are filters between the BMS and the Celeris network for preventing enterprise-wide network communications from interfering with room-level control communications.
- The data servers are configuration tools.
  - These servers store configuration, diagnostic and remote access tools for commissioning and troubleshooting purposes.
  - These servers maintain the Celeris database, including all set points and configuration properties.
  - These servers generate and maintain the map files for integrated points.
  - These servers map room-level devices and points automatically for configuration and/or integration.

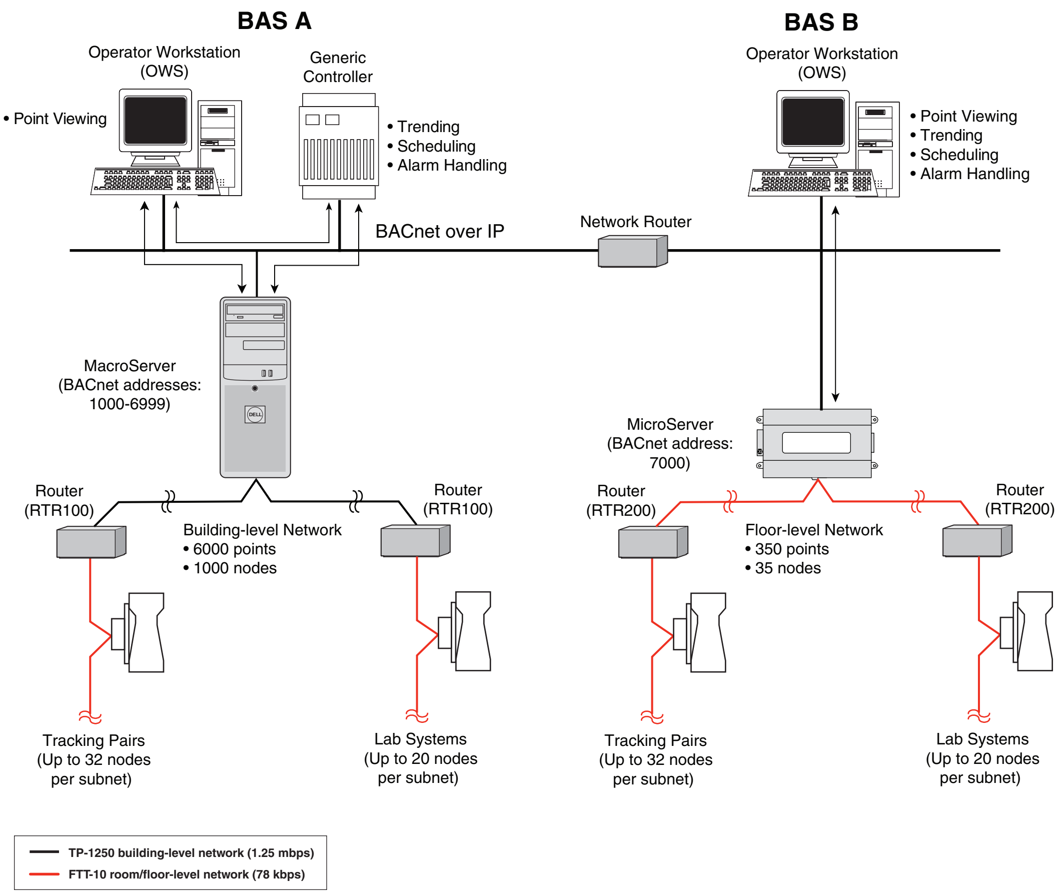


Figure 4-20. Network integration with two building automation systems (BASs).

Points Available for Integration in the Celeris Environmental Control System

Individual Valve Points
- Valve flow feedback (read only)
- Valve flow set point (read only)
- Jam alarm (read only)
- Flow alarm (read only)

Zone Balance Control
- Total supply flow (read only)
- Total exhaust flow (read only)
- Zone offset (read only)
- Zone offset set point (read-write)
- Diversity alarm (read only)

Temperature Control
- Average space temperature (read only)
- Occupied heating set point (read-write)
- Occupied cooling set point (read-write)
- Unoccupied heating set point (read-write)
- Unoccupied cooling set point (read-write)
- Standby heating set point (read-write)
- Standby cooling set point (read-write)
- Effective temperature set point (read only)
- Auxiliary temperature set point (read-write)

Thermal Anticipatory Control
- Discharge air temperature (read only)
- Discharge temperature set point (read only)
- BTU delivered to the space (read only)

Humidity Control
- Space humidity (read only)
- Humidity set point (read-write)

Occupancy Control
- Occupancy mode (read only)
- Occupancy override (read-write)
- Bypass time set point (read-write)
- Bypass time remaining (read only)
- Occupied minimum ventilation set point (read-write)
- Unoccupied minimum ventilation set point (read-write)

Emergency Mode Control
- Emergency mode (read only)
- Emergency override (read-write)

Fume Hood Control
- Face velocity (read only)
- Face velocity set point (read only)
- User status (read only)
- Sash position (read only)
- Sash height alarm (read only)
- Broken sash alarm (read only)
- Emergency override (read only)

Progressive Offset Control
- Space differential pressure (DP): Zone absolute pressure and reference absolute pressure (all read only)
- DP set point (read-write)
- DP warning set point (read-write)
- DP alarm set point (read-write)
- Freeze mode duration (read-write)
- Freeze mode time remaining (read only)
- Freeze mode alternate offset set point (read-write)
- Freeze mode override (read-write)

Integration Partners

Celeris BACnet integration was first developed in 1998 and continues to be the primary method to integrate with various BMS vendors. Interoperability is an ongoing process and we continuously qualify and refine interfaces with a large number of integration partners including:

- Alerton
- American Automatrix
- Andover Controls
- Automated Logic
- Carrier
- Cimetrics BACnet/OPC
- Delta
- Eagle Technology
- Honeywell
- Intellution iFix
- Invensys
- Johnson Controls
- Reliable Controls
- SCADA Engine
- Siemens
- Tridium
- Trane
- WonderWare

NOTE: Each BMS vendor will require unique hardware and software on their end to accomplish this integration. Phoenix Controls is committed to creating integration partners and will work with the BMS vendor of choice to create the necessary interface to accomplish the system integration for a building owner. Contact Phoenix Controls for the current status of BMS vendor integration solutions.

Although the Celeris Environmental Control System is fully interoperable, the system can operate as an independent, standalone control solution. All control, fail-safe and alarm strategies are implemented at the room level. All control, system status, and alarm data are available to the BMS, and as a convenience, many set points may be written by an operator from the BMS workstation.

Integration Solution #2: Traccel Room Controller

The Traccel Room Controller is a standalone, valve-mounted, room-level controller. It has sufficient physical inputs and outputs to connect all of the temperature sensing and control elements, as well as two variable air volume flow control valves, to control the ventilation rate, volumetric offset and space comfort of a typical biology lab, animal holding room, procedure room, airlock or corridor. It offers a more cost-effective solution for environmental control for the basic room-level control functions than the Celeris product line and allows for direct integration on the BAS vendor's LonWorks communications network.

The Traccel Room Controller is designed for use primarily on an open LON network; however, it may also be used in conjunction with the Celeris system and integrated with a MicroServer or MacroServer. The Traccel Room Controller is certified to the LonMark standard SCCVAV Object type 8502 as a Space Comfort Controller, Variable Air Volume Functional Profile.

As a standalone device, the Traccel Room Controller implements the desired room-level control strategy, as well as passing desired data to the BMS system. Because the Traccel Room Controller communicates on the 78 K FTT-10 communications channel, it will connect to the BAS through a floor- or room-level controller in most instances.

The Traccel Room Controller can reside on the same LON network as other LonWorks-based devices. Standard LonWorks guidelines for the number of devices and network topologies apply. The Traccel Room Controller supports a large complement of network variables that support either binding or polling.

For larger installations, LonWorks routers and repeaters may be used to extend the network. Traccel Room Controllers can be connected to any Celeris network and integrated through either a MicroServer or MacroServer, if a BACnet interface is preferred.

Figure 4-21. A direct LonTalk integrated network with the Traccel Room Controller.

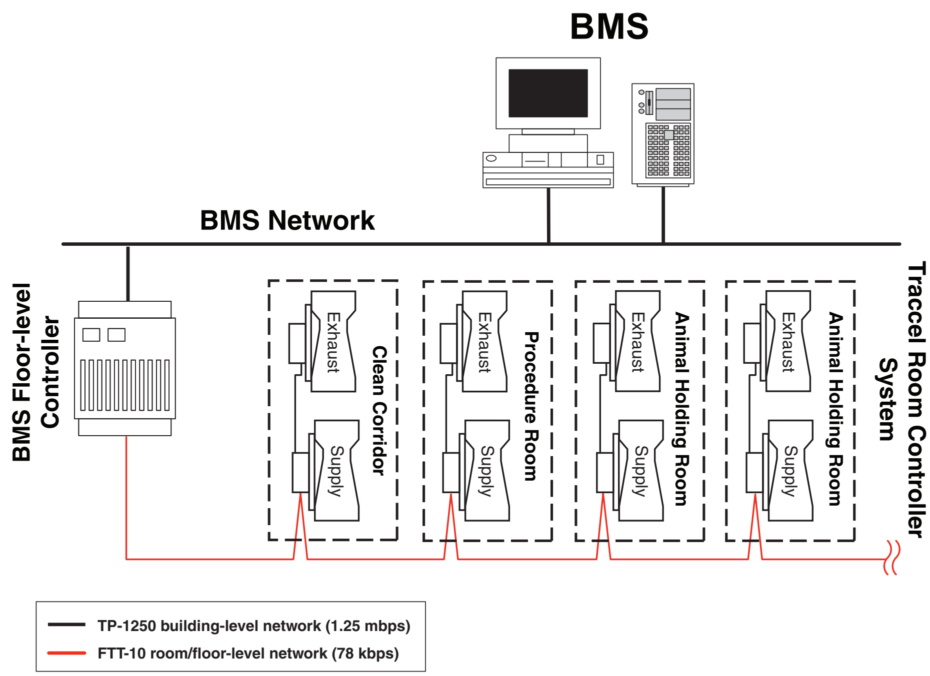
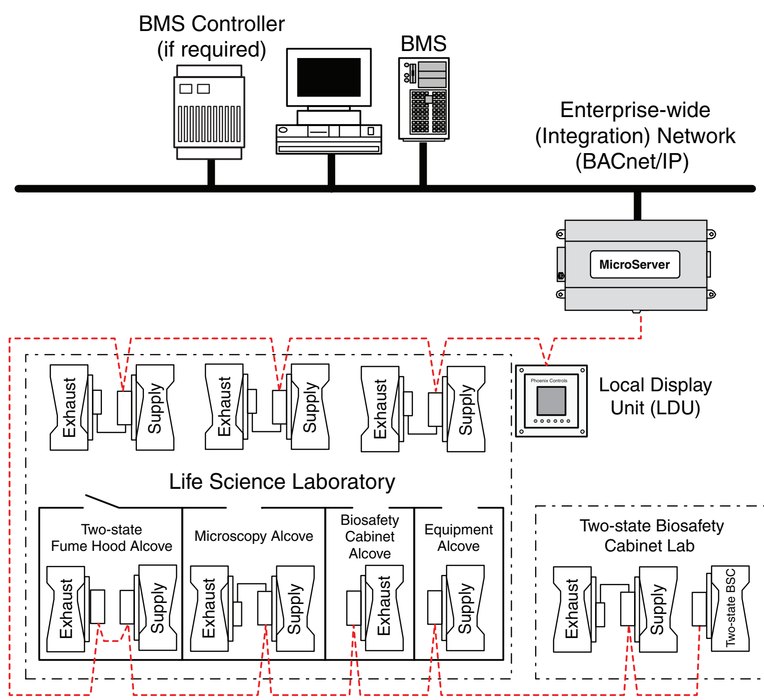


Figure 4-22. A Traccel Room Controller network integrated via BACnet.



Points Available for Integration in the Traccel Room Controller

Zone Balance Control

- Auxiliary supply flow demand percent (read-write)
- BMS zone flow offset set point (read-write)
- Effective zone volumetric offset set point (read only)
- Zone volumetric offset feedback (read only)
- BMS minimum supply flow set point (read-write)
- Supply valve flow set point (read only)
- Supply valve flow feedback (read only)
- Exhaust valve flow feedback (read only)
- Zone total supply flow (read only)
- Zone total exhaust flow (read only)
- BMS HVAC flow override command (read-write)
- BMS HVAC emergency override (read-write)
- Unit status output (read only)
- Application mode input (read-write)
- Current alarm status of all alarm bits (read only)
- Summary of alarm activity (read only)
- Exhaust valve flow set points (read only)

Temperature Control

- Space temperature sensor input (read-write)
- Occupied temperature set point (read-write)
- Occupied temperature set point offset input (read-write)
- Effective primary temperature control loop set point (read only)
- Effective space temperature (read only)
- Auxiliary temperature set point input (read-write)
- Auxiliary temperature control loop command (read only)
- Unoccupied cooling set point (read-write)
- Unoccupied heating set point (read-write)
- Discharge air temperature (read only)
- Terminal load (read only)
- Local temperature set point lever enable/scaling input (read-write)

Occupancy Control

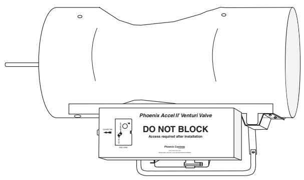
- Occupancy override input (read-write)
- Occupied sensor input (read-write)
- Occupancy mode status (read only)
- Bypass active remaining time output (read only)

Table of Contents

This chapter offers a description of the Phoenix Controls laboratory product line. The components are engineered to deliver reliable, effective control.

5 System Components

Photos by Joe Greene Photography



Accel II Valve (analog)

Accel® II Valve (analog)

The Phoenix Controls Accel II Venturi Valves combine a mechanical, pressure-independent regulator with a high-speed position/airflow controller to meet the unique requirements of airflow control. These valves can be used in constant volume, two-position, or VAV applications—all designed to maximize flow performance while reducing related noise. Valves for VAV applications may be either electrically or pneumatically actuated.

- Pressure-independent operation: All valve types include an immediate response mechanical assembly to maintain airflow set point as duct static pressure varies.
- Airflow control: By positioning the flow rate controller assembly, the airflow can be adjusted.

Accel II valves are available in:

- Constant volume (CVV series) for maintaining an airflow set point under variable static pressure conditions
- Two-position (PEV/PSV series) for high/low flow control (pneumatic only)*
- Base upgradable (BEV/BSV series) for pneumatic flow control with feedback option and upgradability to VAV (pneumatic only)*
- VAV (EXV/MAV series) with VAV closed-loop feedback control (pneumatic or electric)**

Feature/Option	Constant Volume (CVV)	Two-position (PEV/PSV) Pneumatic	Upgradable (BEV/SV) Pneumatic	VAV (EXV/MAV) Pneumatic	VAV (EXV/MAV) Electric
Control type	C Constant Volume	P Pneumatic	B Base Upgradable	A Analog	A Analog
Flow feedback signal	—	—	Option	✓	✓
Falsafe	Fixed	NO/NC	NO/NC	NO/NC	NO/NC or last position
Factory-insulated valve body (supply)	Option	✓	✓	✓	✓
Field-adjustable flow	✓	✓	✓	✓	✓
Flow alarm via feedback circuit	—	—	—	✓	✓
Flow alarm via pressure switch	Option	Option	Option	Option	Option
Low-noise diffuser construction†	✓	✓	✓	✓	✓
Single 14-inch	✓	Without Flow Feedback	N/A	N/A	N/A
Dual 14-inch	✓	N/A	N/A	N/A	N/A

** 14-inch PxV and BxV are only available as a single valve with pneumatic actuator.*

*** Not available in the 14-inch valve size.*

NOTE: All valves include pressure-independent, factory-calibrated position controllers, and are available in flows from 35-10,000 CFM (60-16,900 m^3/hr). Accel II valves are designed to reduce sound over all frequencies, but significantly target the lower bands (125-500 Hz) to help eliminate the need for silencers.

Specifications

Construction

- 16 ga. spun aluminum valve body with continuous welded seam
- Valve bodies available as uncoated aluminum or with corrosion-resistant baked phenolic coatings
- Composite Teflon® shaft bearings
- Spring grade stainless steel spring, and polyester or PPS slider assembly
- Supply valves* insulated with 3/8" (9.5 mm) flexible closed-cell polyethylene. Flame/smoke rating 25/50. Density is 2.0 lb/ft^3 (32.0 kg/m^3).

Operating Range

- 32-122 °F (0-50 °C) ambient
- 10-90% non-condensing RH

Sound

Designed for low sound power levels to meet or exceed ASHRAE noise guidelines.

Performance

- Pressure independent over a 0.6"-3.0" WC (150-750 Pa) drop across valve
- Volume control accurate to ±5% of airflow command signal
- No additional straight duct runs needed before or after valve
- Available in flows from 35-10,000 (60-16,990 m^3/hr)
- Response time to change in command signal: < 1 second
- Response time to change in duct static pressure: < 1 second

VAV Controller

Controller Power:

- ±15 Vdc, ±5% @ 0.145 amp (pneumatic only)
- 0-10 Vdc command signal
- 0-10 Vdc flow feedback signal
- 0-10 Vdc alarm signal

Pneumatic Actuation:

- Only applicable to PEV, PSV, BEV/BSV and EXV/MAV-N (pneumatic control type)
- 20 psi (-0/+2 psi) with a 20 micron filter main air required (except for CVV)
- Compressor sizing: Accel II valves are not continuous air-consuming devices. For compressor sizing, use:
    - single and dual valves: 10 scim
    - triple and quad valves: 20 scim

Electric Actuation:

- 24 Vac (±15%) @ 60 Hz
    - single and dual valves: 96 VA
    - triple and quad valves: 192 VA

* Not applicable to CVV series.

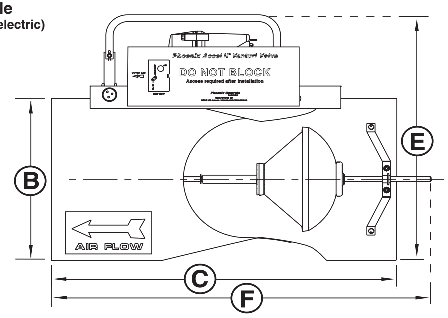
Teflon is a registered trademark of DuPont Co.

Valve Sizes, Dimensions, Weights and Operating Ranges

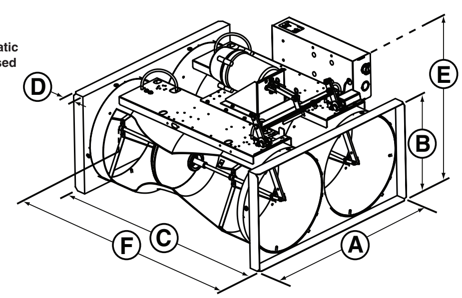
Accel II analog valves are available in four specific model sizes: 8, 10, 12 and 14. (For actual dimensions, refer to the chart on the following page.) In order to increase flow capacity, multiple valves may be assembled to operate as a unit.

For complete information on valve dimensions, weights and operating ranges, see page 72.

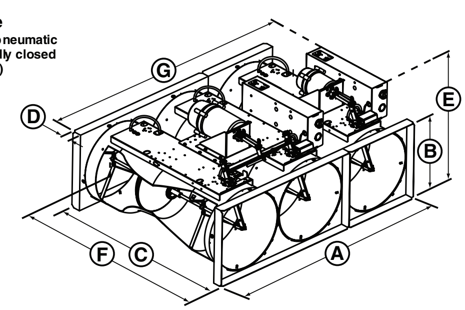
Single
(EXV-electric)



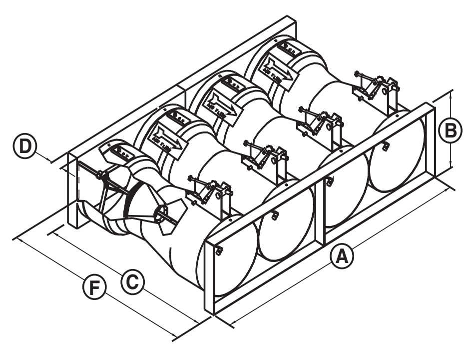
Dual
(MAV-pneumatic normally closed shown)



Triple
(MAV-pneumatic normally closed shown)



Quad
(CVV shown)



Accel II® Valve (analog) Sizes, Dimensions, Weights and Operating Ranges (continued)

Valve Dimensions														
Valve Diameter in Inches	A*		B*		C		D		E**		F		G	
	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm
8	—	—	7.88	200	23.50	597	—	—	14.13	359	28.00	711	10.13	257
10	—	—	9.67	246	21.75	552	—	—	16.13	410	26.20	665	11.20	284
12	—	—	11.84	301	26.81	681	—	—	18.13	461	32.56	827	12.13	308
14	—	—	13.88	353	30.00	762	—	—	21.43	544	38.09	968	13.52	343
2-10	20.13	511	10.13	257	24.75	629	1.5	38	16.77	426	27.70	704	21.52	547
2-12	24.13	613	12.13	308	29.81	757	1.5	38	18.75	476	34.60	879	24.76	629
3-12	37.06	941	12.13	308	29.81	757	1.5	38	18.75	476	34.60	879	36.77	934
4-12	48.26	1226	12.13	308	29.81	757	1.5	38	18.75	476	34.60	879	48.65	1236
2-14	30.00	762	15.00	381	33.00	838	1.5	38	21.43	544	38.09	968	28.90	734
3-14*	45.00	1143	15.00	381	33.00	838	1.5	38	21.43	544	38.09	874	42.27	1074
4-14*	60.00	15.24	15.00	381	33.00	838	1.5	38	21.43	544	38.09	874	57.13	1452

** outer dimension*
*** maxiumum of all valve types (some configurations may be smaller)*

Valve Weights				
Valve Diameter in Inches	Weight (CVV valves)		Weight (all others)	
	lbs	kg	lbs	kg
8	7	3.2	12	5.5
10	7	3.2	13	6.0
12	9	4.1	16	7.3
14	13	6.0	20	9.1
2-10	18	8.2	30	13.6
2-12	23	10.4	36	16.3
3-12	32	14.5	52	23.6
4-12	46	20.9	72	32.7
2-14	37	16.8	50	22.7
3-14	40	18.2	70	31.8
4-14	74	33.6	100	45.4

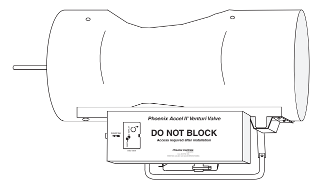
Operating Ranges			
Valve Size	Flow (CFM) 0.6-3" WC	Flow (m^3/h) 150-750 Pa	Flow (l/s) 150-750 Pa
8	35-700	60-1175	17-330
10	50-1000	85-1700	24-472
12	90-1500	150-2500	43-708
14	200-2500	339-4247	95-1180
2-10	100-2000	170-3350	47-943
2-12	180-3000	300-5000	85-1415
2-14	400-5000	680-8495	189-2360
3-12	270-4500	450-7500	127-2123
3-14*	600-7500	1019-12,743	283-3540
4-12*	360-6000	600-10000	170-2831
4-14*	800-10,000	1359-16,990	370-4719

** CVV only*

Celeris® Valves (digital)

The Phoenix Controls Celeris Venturi Valves combine a mechanical, pressure-independent regulator with a high-speed position/airflow controller to meet the unique requirements of airflow control. These valves can be used in constant volume, two-position, or VAV applications—all designed to maximize flow performance while reducing related noise. Valves for VAV applications may be either electrically or pneumatically actuated.

- Pressure-independent operation: All valve types include an immediate response mechanical assembly to maintain airflow set point as duct static pressure varies.
- Airflow control: By positioning the flow rate controller assembly, the airflow can be adjusted.



Celeris valves are available in:

- VAV (EXV/MAV series) with VAV closed-loop feedback control, low-speed electric actuation for non-fume hood applications, and high-speed electric or pneumatic actuation for fume hood applications.
- Standard (Option S) and Low-leakage (Option L)–Both designs are intended for use in critical airflow applications, where isolating the HVAC system from the room is necessary.
- When networked with a twisted pair cable, Celeris valves form a room-level control system, providing ventilation, volumetric offset, temperature, humidity, occupancy and emergency control.

Specifications

Construction

- 16 ga. spun aluminum valve body with continuous welded seam
- Valve bodies available as uncoated aluminum or with corrosion-resistant baked phenolic coatings
- Composite Teflon® shaft bearings
- Spring grade stainless steel spring and polyester or PPS slider assembly
- Supply valves* insulated with 3/8” (9.5 mm) flexible closed-cell polyethylene. Flame/smoke rating 25/50. Density is 2 lb/ft3 (32 kg/m3).

Operating Range

- 32-122 °F (0-50 °C) ambient
- 10-90% non-condensing RH

Performance

- Pressure independent over a 0.6”-3.0” WC (150-750 Pa) drop across valve
- Volume control accurate to ±5% of airflow command signal
- No additional straight duct runs needed before or after valve
- Available in flows from 35-5000 CFM (60-8495 m3/hr)*
- Response time to change in command signal:
  - < 1 second (control type M and N)
  - < 1 minute (control type L)
- Response time to change in duct static pressure: < 1 second

Pneumatic Actuation

- EXV/MAV-N (pneumatic control type)**
- 20 psi (-0/+2 psi) with a 20 micron filter main air required
- Compressor sizing: Accel II valves are not continuous air-consuming devices. For compressor sizing, use:
  - single and dual valves: 10 scim
  - triple and quad valves: 20 scim

Sound

Designed for low sound power levels to meet or exceed ASHRAE noise guidelines.

VAV Controller

Power:

- 24 Vac (±15%) @ 50/60 Hz

Power Consumption:

Control Type	Single	Dual
L (low-speed electric)	13 VA	17 VA
M (high-speed electric)	70 VA	96 VA
N (pneumatic)	11 VA	11 VA

I/O available for connecting field devices:

- 3 universal inputs. Accepts volt, mA, ohms or NTC 2 or 3 thermistor signals.
- 1 digital input
- 2 analog outputs. Provides volt or mA signals.
- 1 digital output (Type C, 1 amp @ 24 Vac/Vdc)
- Input accuracy
  - Voltage, current, resistance: ±1% full scale
- Output accuracy
  - 0 to 10 Vdc: ±1% full scale into 10 kΩ minimum
  - 4 to 20 mA: ±1% full scale into 500 Ω +0/-50 Ω

Agency compliance:

- CE
- CSA
- FCC Part 15, Subpart J, Class A

Room-level communcations:
FTT-10, 78 KB, bus topology, LonTalk™ network

Building-level communications:
TP-1250, 1.2 MB, bus topology, LonTalk™ network

* Celeris triples and quads represent 2 nodes on the system (main and booster)
** Not available with 14-inch valve

Teflon is a registered trademark of DuPont Co.

LONWORKS is a registered trademark of Echelon Corp.

Specifications (continued)

Feature/Option	Variable Air Volume (VAV) (EXV/MAV) Celeris		
Control type	L	N*	M
Actuator type	Low-speed electric	Pneumatic	High-speed electric
Flow feedback signal	✓	✓	✓
Falsafe	Last position	NO/NC	NO/NC, last position
Factory-insulated valve body (supply)	✓	✓	✓
Field-adjustable flow	✓	✓	✓
Flow alarm via feedback circuit	✓	✓	✓
Flow alarm via pressure switch	Option	Option	✓
Low-noise diffuser construction†	✓	✓	✓

** Not available in the 14-inch valve size.*

*** All valves include pressure-independent, factory-calibrated position controllers, and are available in flows from 35-5000 CFM (60-8495 m^3/hr).*

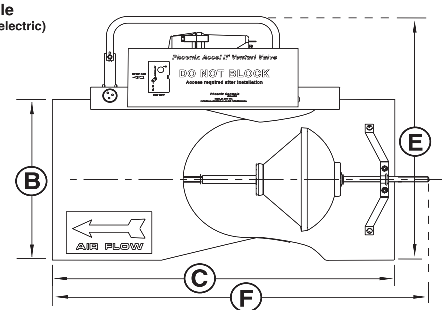
NOTE: Accel II valves are designed to reduce sound over all frequencies, but significantly target the lower bands (125-500 Hz) to help eliminate the need for silencers.

Valve Sizes, Dimensions and Operating Ranges

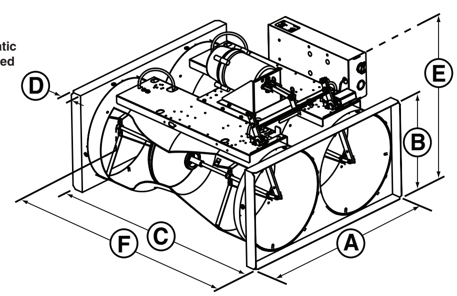
Accel II digital valves are available in four specific model sizes: 8, 10, 12, and 14-inch. In order to increase flow capacity, multiple valves may be assembled to operate as a unit.

For complete information on valve dimensions, weights and operating ranges, see page 72.

Single
(EXV-electric)

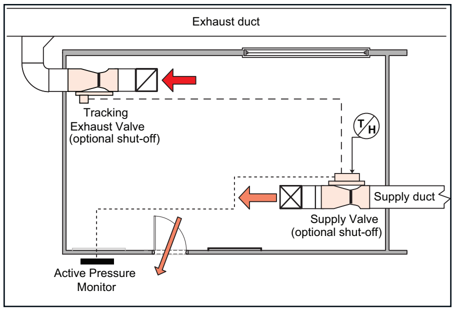


Dual
(MAV-pneumatic normally closed shown)



Flow and Operating Ranges: Celeris Shut-off Valve*			
Valve Size	Operating Range in CFM (m^3/hr)		Pressure Drop Across Valve
	Single	Dual	
8	35-600 (59-1019)	–	0.6-3" WC (150-750 Pa)
10	50-850 (85-1444)	1000-1700 (170-2888)	
12	90-1900 (153-2208)	180-2600 (306-4417)	

** Shut-off Valves are available in control types L and M only.*



The Traccel-TX valve can maintain positive, negative or neutral directional airflow with variable air volume (VAV) temperature and humidity control.

Traccel® Family of Valves (digital)

The Phoenix Controls Traccel® Family of Valves is designed specifically for the ventilation requirements of demanding spaces in life science lab facilities, where ventilation zone control, energy savings and reducing maintenance costs are an important part of business operations.

These valves provide a safe, comfortable working environment for research in a single standalone lab or an entire research complex. The flexibility, airflow turndown and added configuration options make it an ideal solution for modular mixed-use facilities.

Life science research spaces designed with an open lab and fume hood alcoves require a unique ventilation control solution. As airflow or pressurization requirements change, the impact on adjacent spaces like bench work areas, offices and common corridors contribute directly to the balance of the entire lab. The adjacent spaces must adapt to airflow changes controlled by critical spaces like fume hood alcoves.

The Traccel Family of Valves is a cost-effective platform for ventilation control applications for these adjacent spaces. It uses the LonWorks Communication Protocol to develop peer-to-peer control architecture with high-speed Celeris® or normal-speed Traccel Valve Controllers for the desired research space control strategy.

System Benefits

- Factory characterization reduces system commissioning time
- Pressure-independent valves avoid rebalancing costs
- No flow sensors to maintain
- High turndown ratios contribute to reducing energy costs
- Flexibility to handle space configuration changes

Product Designs and Models

The Traccel Family of Valves is available in standard (Option S) and low-leakage (Option L) designs. Both designs are intended for use in critical airflow applications, where isolating the HVAC system from the room is necessary.

Three venturi valve models are available in the Traccel family:

Product	Description
Traccel-TP (Tracking Pair VAV)	To meet the need of directional airflow, Traccel-TP features tracking valve pairs that maintain a prescribed CFM offset to enable accurate space pressurization and complete room climate control.
Traccel-TX (Enhanced Tracking Pair VAV)	For tracking pair applications in demanding spaces, Traccel-TX provides extra I/O to meet the needs of humidity control and pressure monitoring, plus optional shut-off capability for decontamination procedures.
Traccel-SO (Supply-only VAV)	In VAV applications where ducted exhaust is sufficient to meet local codes and engineering guidelines, Traccel-SO provides a cost-effective supply valve when no tracking exhaust valve is required.

Specifications

Construction (includes A and S valve designs)

- 16 ga. spun aluminum valve body with continuous welded seam
- Aluminum valve bodies available as uncoated aluminum or with corrosion-resistant baked phenolic coatings
- Composite Teflon® shaft bearings
- Spring grade stainless steel spring and PPS slider assembly
- Supply valves insulated with 3/8" (9.5 mm) flexible closed-cell polyethylene. Flame/smoke rating 25/50. Density is 2 lb/ft^3 (32 kg/m^3)

Construction, Low-leakage (L valve designs)

Same as above with the following added:

- Cone gasket material:
  - Class A: Neoprene
  - Class B: Viton
- Seal wheel material: Polypropelene

Operating Range

- 32-122 °F (0-50 °C) ambient
- 10-90% non-condensing RH

Performance

- Pressure independent over a 0.3-3" WC (74-750 Pa) drop across valve
- Volume control accurate to ±5% of airflow command signal
- No additional straight duct runs 10,000 needed before or after valve
- Available in flows from 35-10,000 CFM (59-16,990 m^3/hr)
- Response time to change in command signal: <1 minute

Sound

- Designed for low sound power levels to meet or exceed ASHRAE noise guidelines

Traccel Valves

Power:

- 24 Vac (±15%) @ 50/60 Hz

Power consumption (using proportional reheat control):

- Single 8", 10", and 12": 13 VA
- Single 14": 20 VA
- Dual 10", 12", 14": 20 VA

Power consumption (using floating point reheat control):

- Single 8", 10", and 12": 20 VA
- Single 14": 26 VA
- Dual 10", 12", and 14": 26 VA

Input accuracy:

- Voltage, current, resistance: ±1% full scale

Output accuracy:

- 0 to 10 Vdc: ±1% full scale into 10 K minimum
- 4 to 20 mA: ±1% full scale into 500 +0/-50

Interoperability:

- Based on LonWorks technology for peer-to-peer communication between room controllers
- LonMark certified according to the Interoperability Guidelines Version 3.4
- LonMark functional profile SCC-VAV #8502

Agency compliance:

- CE
- CSA
- FCC Part 15, Subpart J, Class A
- Optional IP54 Controller Protection

Room-level communications:

- FTT-10, 78 KB, LonTalk™ network

LonMark 3.4

Valve Sizes, Dimensions and Operating Ranges

For complete information on valve dimensions, weights and operating ranges, see page 72.

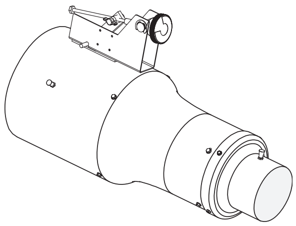
Standard Shut-off Valve and Low-leakage Shut-off Valve static pressure information is available on pages 46-47.

Flow and Operating Ranges: Traccel Shut-off Valve*

Valve Size	Operating Range in CFM (m^3/hr)		Pressure Drop Across Valve
	Single	Dual	
8	35-600 (59-1019)	–	0.6-3" WC (150-750 Pa)
10	50-850 (85-1444)	1000-1700 (170-2888)	
12	90-1900 (153-2208)	180-2600 (306-4417)	

** Shut-off Valves are available in control types L and M only.*

Compact Cage Rack Valves

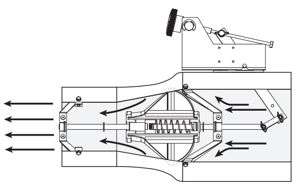


Constant volume compact cage rack valve

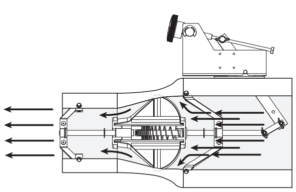
Phoenix Controls Constant Volume Compact Cage Rack Valve combines a factory-calibrated, field tunable flow rate setting with a mechanical, pressure-independent flow regulator to meet the unique requirements of ventilated cage rack connections to building ventilation systems.

- Short valve body for ease of installation below the ceiling.
- Precise airflow control: The flow rate controller assembly is factory-calibrated to a precise constant volume flow set point.
- Easy-to-use manual setting; includes graduated scale for reference to valve position.
- Self-balancing pressure-independent operation: The cage rack valve compensates automatically for system static pressure fluctuations to maintain the airflow set point.
- Simple operation: The valve requires no electrical power or pneumatics to operate, nor are there any flow probes. This simplifies the operation and installation, plus eliminates maintenance.

Operation



When there is low static pressure, less force is applied to the cone, which causes the spring within the cone to expand, pulling the cone away from the venturi. The combination of low pressure and a large open area provides the desired flow.



As static pressure increases force on the cone, the spring compresses and the cone moves into the venturi, reducing the open area. Higher pressure and the smaller opening combine to maintain flow set point.

Volume Control

The valve's shaft/cone assembly is factory pre-set to the flow listed on the room schedule sheet at the time the valve is ordered. The flow setting is easily adjusted in the field to accommodate the wide variety of ventilated cage racks.

Pressure-independent Control

All Phoenix valves maintain a constant airflow by automatically and instantaneously adjusting to changes in static pressure. Each valve has a cone assembly with an internal spring designed to compensate for these changes in duct pressure (see figures on the left).

Specifications

Construction
- 16 ga spun aluminum valve body with continuous welded seam
- Composite Teflon® shaft bearings
- Spring grade stainless steel spring and PPS slider assembly
- Optional white powder coating

Operating Range
- 32-122 °F (0-50 °C) ambient
- 10-90% non-condensing RH

Sound
- Designed for low sound power levels to meet or exceed ASHRAE noise guidelines
- Accel® II valves are designed to reduce sound over all frequencies, but significantly target the lower bands (125-500 Hz) to help eliminate the need for silencers

Performance
- Pressure independent over a 0.6"-3.0" WC (150-750 Pa) drop across valve
- Volume control accurate to ±10%, 5 CFM (10 m^3/hr) of airflow set point
- Flow range: 30-210 CFM (50-356 m^3/hr), factory pre-set to airflow value indicated on order.
- No additional straight duct runs needed before or after valve
- Response time to change in duct static pressure: < 1 second
- Optional low static pressure alarm via a pressure switch
- Field adjustable flow set point

CE

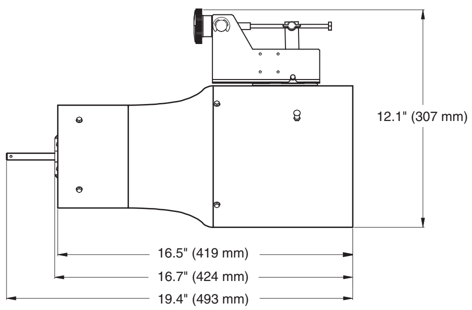
Installation

Compact Cage Rack Valves can be mounted in the ductwork above the ceiling, on a shelf mounted to the holding room wall above the rack, or directly to the rack.

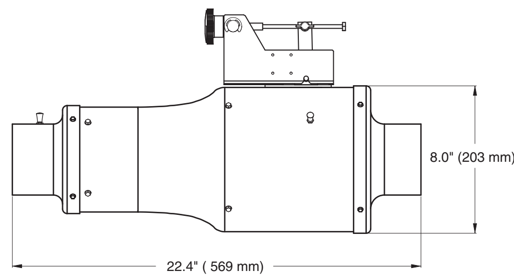
Maintenance

Compact Cage Rack Valves require no ongoing preventive maintenance. Once the balancer has verified the volume, the valves will provide years of continuous operation.

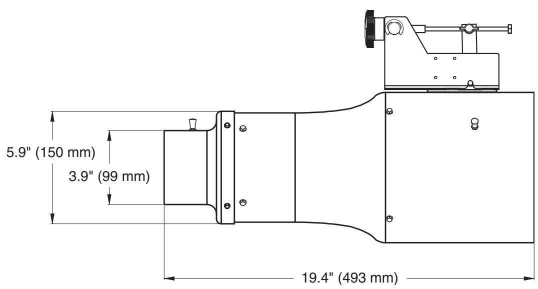
Dimensions and Weight



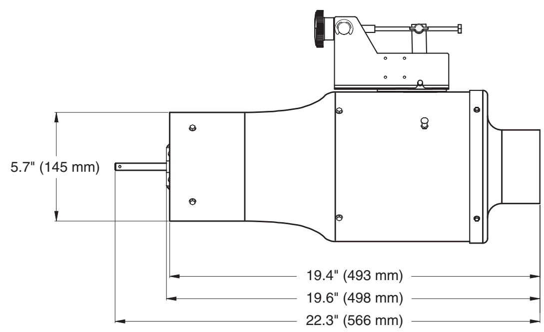
Rack Valve, No Reducers



Rack Valve, Two Reducers, Option G



Rack Valve, One Reducer on Discharge, Option K



Rack Valve, One Reducer on Inlet, Option J

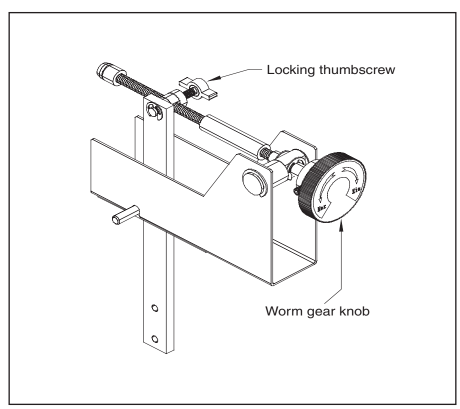
Weight

- Approximate weight: 8 lbs (3.6 kg)
- The weight given above is approximate and is listed for reference only. For shipping, add 6 lbs (2.7 kg) for cage rack valves.

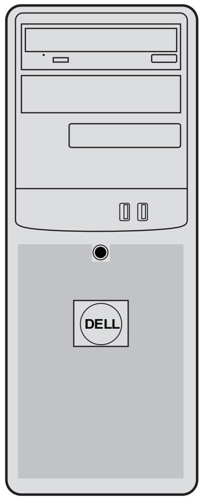
Points and Wiring *(see submittal wiring diagram for project-specific details)*

Wiring is required only when a pressure switch option has been ordered. Wire between the common and normally open terminals on the pressure switch.

- Switch closed = normal operation with fans running
- Switch open = alarm condition (low or no differential static pressure)



Field flow adjustment.



MacroServer™

MacroServer™

The Celeris® MacroServer™ facilitates communication between the Celeris LonWorks®-based environmental control system and BACnet capable Building Management Systems (BMSs). The server performs bidirectional translations between LonTalk and BACnet to manage read requests and write commands between the BMS and the Celeris room-level devices, ensuring safe and reliable communications. The server also hosts the Celeris LNS database, along with a Configuration plug-in and several diagnostic utilities. The server functions as a data concentrator, collecting thousands of points from room-level devices and making these available to the BMS through a single Ethernet/IP connection.

The MacroServer is recommended for medium- to large-scale projects.

Features

- Integration flexibility with most BMS vendors offering BACnet™
- Supports up to 2000 devices or 6000 points
- Built-in 56 K modem for remote configuration and/or troubleshooting
- Self-ventilated enclosure
- Universal power input, 85-264 Vac

Specifications

Enclosure
Tower server enclosure

Dimensions
17.5" H x 6.6" W x 18" D
(444.5 mm H x 167.6 mm W x 457.2 mm D)

Approx. Weight
38 lbs (17.3 kg)

Operating Temperature Range
50-95 °F (10-35 °C) ambient

Operating Humidity Range
8-85%, non-condensing

Power Requirements
- 305-watt switchable power supply,
- 115 Vac (9 A) or 230 Vac (4.5 A)
- 50/60 Hz

Modem
Supports communications to 56 K

Microprocessor
Pentium D, 2.8 GHz (minimum)

Memory
1 GB RAM (minimum)

Data Ports
7 USB 2.0 ports: 2 in the front of the computer and 5 in the back

Disk Drive
1 internal CD-ROM drive 48x speed

Hard Drive
2 internal SATA drives, 80 GB each (minimum)

Network Interface
- 10 Base T/100 Base Tx/1000 Base Tx
- Ethernet adapter

Operating System
Windows XP Professional

BACnet is an exclusive trademark of ASHRAE.
Windows XP is a trademark of Microsoft Corporation.
LonWorks is a trademark of Echelon Corporation.

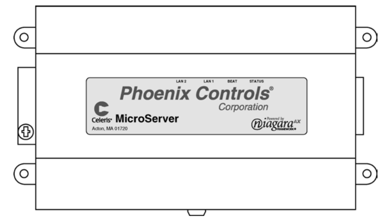
Communication Protocols

BMS Network Protocol	
BMS protocol	BACnet over Ethernet BACnet over IP
BMS network connection	RJ-45
Implementation	Conformance Class 3 BIBBS-ASC (Application Specific Controller)
Data transfer rates (points per second)	Read requests/second: • 100 sustained • 300 peak Write commands/second—30 maximum
Celeris Network Protocol	
Building network	ANSI 791.1—LonTalk protocol TP-1250 transceiver
Celeris network connection	22 AWG, Level IV, twisted-pair cable (no shield)

MicroServer™

The Celeris® MicroServer™ facilitates communication between the Celeris LonWorks®-based environmental control system and the BACnet-capable Building Management Systems (BMSs). The server performs bidirectional translations between LonTalk and BACnet to manage read requests and write commands between the BMS and the Celeris room-level devices, ensuring safe and reliable communications. The server functions as a room-level, suite level or floor-level data concentrator, collecting data from room-level devices and making these available to the BMS through a single Ethernet/IP connection.

The MicroServer is recommended for small- to medium-scale projects.



Features

- Integration flexibility with most BMS vendors offering BACnet™
- Supports up to 35 devices or 350 points
- Small compact enclosure
- All solid-state design; no moving fans or hard drives
- Internal battery provides graceful shutdown on power loss and sustains the MicroServer over power fluctuations
- Flexible mounting options

Specifications

Enclosure
- Plastic, DIN rail or screw-mount chassis, plastic cover
- Cooling–Internal air convection

Dimensions
- 4.820" H x 6.313" W x 2.438" D
- (12.24 mm H x 16.04 mm W x 6.19 mm D)

Approx. Weight
1.7 lbs (0.8 kg)

Operating Temperature Range
32-122 °F (0-50 °C)

Storage Temperature Range
32-140 °F (0-60 °C)

Operating Humidity Range
5-95%, non-condensing

Power Requirements
The MicroServer requires 15 Vdc to operate. Choose from these power supply configurations:
- PWR–DIN rail mounted
- 24 Vac/dc power supply module (8.5 VA AC/8.5 W DC)
- Attaches to connector on right side of MicroServer
- WPX = Wall-mounted power modules (X represents different plug configurations)
- Universal input–90-264 Vac @ 0.5 A, 50/60 Hz
- Output–15 Vdc @ 1 A
- Power cord–70" (1.8 m) long
- WPA–US/Japanese style plug
- WPE–European/Asian style plug
- WPU–UK style plug

Microprocessor
IBM PowerPC 405EP 250 MHz processor

Memory
64 MB SDRAM and 64 MB serial flash

Data Ports
- 2 Ethernet ports, 10/100 mbps (RJ-45 connectors)
- 1 RS 232 port (9-pin D-shell connector)
- 1 RS 485 non-isolated port (3-screw connector on base board)
- 1 78-kbps FTT10 A LonTalk (pluggable TP connector 22 AWG)

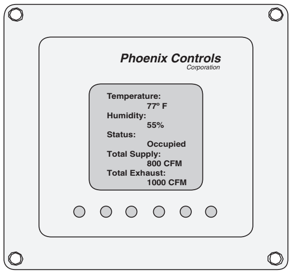
Network Interface
- BACnet over Ethernet/IP 10/100 mbps
- LonTalk FTT-10A, 78 kbps
- Operating System
- QNX RTOS
- IBM J9 JVM Java Virtual Machine
- Niagara^{AX}

Agency Listings
- UL 916, C-UL listed to Canadian Standards Association (CSA) C22.2 No. 205-M1983 “Signal Equipment”
- CE
- FCC part 15 Class A
- C-tick (Australia)

Celeris is an exclusive trademark of Phoenix Controls Corporation.
BACnet is an exclusive trademark of ASHRAE.
LonWorks is a trademark of Echelon Corporation.
Niagara^{AX} is a trademark of Tridium, Inc.
Powered by Niagara is a trademark of Tridium, Inc.

Communication Protocols

BMS Network Protocol	
BMS protocol	BACnet over Ethernet BACnet over IP
BMS network connection	RJ-45
Implementation	Conformance Class 3 BIBBS-BSC (BACnet Building Controller)
Data transfer rates (points per second)	Read requests/second: • 50 sustained • 100 peak Write commands/second—30 maximum
Celeris Network Protocol	
Building network	ANSI 791.1—LonTalk protocol TP-1250 transceiver
Celeris network connection	22 AWG, Level IV, twisted-pair cable (no shield)



Local Display Unit (LDU)

Local Display Unit

The Local Display Unit (LDU), a networked-based user interface panel, displays data and/or provides editing of set point variables for vivariums, biocontainment or laboratory spaces maintained by the Celeris® Environmental Control System. The LDU may be flush or surface mounted on a variety of electrical enclosures. It is intended to be installed in corridors outside of critical environments to provide users with information related to operating conditions inside the space. Using a 128 x 128 pixel graphical display, the LDU can display up to five parameters simultaneously. Each parameter includes a 16-character user defined description and the present value, including units of measure.

The LDU connects to the Celeris room-level network and may be used to display flow, temperature, humidity, control or set point variables available on the Celeris network.

Specifications

__Power__

Voltage
24 Vdc/Vac; ±15%, 50/60 Hz

Consumption
8 VA (13 VA maximum)

Protection
1.5 amp auto reset fuse

__Environmental__

Operating Temperature
32-158 °F (0-70 °C)

Storage Temperature
-4-158 °F (-20-70 °C)

Temperature Relative Humidity
0-90%, non-condensing

__General__

Processor
Neuron® 3158, 8 bits, 10 MHz

Memory
- Flash 64 K (APB applications)
- Flash 64 K (storage)

Clock
Real-time clock chip, accurate to ±1 minute per month

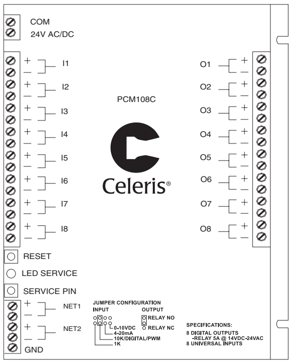
Battery
CR 2032 Lithium battery; retains clock time for 1 year with no power applied

Communication
LonTalk® protocol

Transceiver
TP/FT-10, 78 kbps

Enclosure
- Material: ABS resin
- Color: Off-white
- Dimensions:
  - Flush mount: 6" x 6" x 1.5" (151 x 151 x 38 mm)
  - Din rail mount: 4.5" x 4.5" x 1.5" (113 x 113 x 38 mm)
- Weight: 0.73 lbs (0.33 kg)

Display
- Type: Backlit LCD
- Definition:
  - 128 x 128 pixels
  - 10 lines (5 variables) x 13 characters
- Display area: 2.1" x 2.1" (5.5 cm x 5.5 cm)



Programmable Control Module (PCM)

Programmable Control Module

The Phoenix Controls Programmable Control Module (PCM) series provides a means of connecting additional inputs and outputs to the Celeris room-level network and developing custom control sequences to enhance the control functions already provided. The PCM offers varying numbers of configurable input and output connections, a BASIC-like programming interface for developing custom control applications, and a data logging function to capture trend data from the Celeris room-level network. The PCM adds tremendous power and flexibility to the Celeris environmental control system.

Features

- Connects to Celeris room-level network
- 6, 8, or 12 universal inputs
- 7, 8, or 12 analog/digital outputs
- Data logging function for up to 12,000 events
- Pluggable terminal blocks
- Status indicators for outputs
- Programmable control functions:
  - 10 PID control loops
  - 15 internal timers
  - 50 internal variables
  - 50 internal constants
  - 18 configurable network variable inputs
  - 18 configurable network variable outputs
  - IF/THEN, AND/OR logic functions
  - Arithmetic functions (+, -, *, /)

Specifications

General Specifications
- Processor: Neuron® 3150®; 8 bits; 10 MHz
- Communication: LonTalk® protocol
- Transceiver: TP/FT-10; 78 Kbps
- Clock: Real-time clock chip [N/A on PCM167-E]
- Battery: CR2032 Lithium (for clock) [N/A on PCM167-E]
- Status indicator: Green LEDs on outputs

Enclosure
Controller housing: 18-gauge painted metallic with mounting slots

Dimensions
- PCM167—6.5" H x 5.2" W x 1.5" D (165 x 132 x 38 mm)
- PCM108—7.5" H x 6.5" W x 1.5" D (191 x 166 x 38 mm)
- PCM112—9.0" H x 6.7" W x 1.5" D (229 x 170 x 38 mm)
- PCM188—10.3" H x 8.0" W x 1.8" D (262 x 203 x 45 mm)

Approximate Weight
- PCM167—1.8 lbs (0.8 kg)
- PCM108—2.4 lbs (1.1 kg)
- PCM112—2.9 lbs (1.3 kg)
- PCM188—3.6 lbs (1.6 kg)

Environmental
- Operating temperature 3 °F to 158 °F (-16 °C to 70 °C)
- Storage temperature -4 °F to 158 °F (-20 °C to 70 °C)
- Relative humidity 0 to 90% non-condensing

Power Inputs
- Voltage 24 Vac/Vdc; ±15%, 50/60 Hz
- Protection 5 amp removable fuse
- Must be powered by a 24 Vac, Class 2 power supply

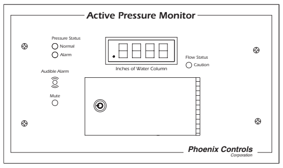
Power Consumption
- PCM167—10 VA (max)
- PCM108—18 VA (max)
- PCM112—28 VA (max)
- PCM188—13 VA (max)

Inputs/Outputs
Type and quantity of I/O are determined by model number.

Agency Compliance
- CE—European Directive 89/336/EEC, Electromagnetic Compatibility
- C/US UL listing for Energy Management Equipment—UL 916/CSA 22.2 # 205-M1983

Under Directive 89/336, the PCM series of products have been designed and manufactured to meet the following standards:
- EN 55022: 1998 B Class; Conducted Emission
- EN 55022: 1998 B Class; Radiated Emission
- EN 61000-4-2: 1995 Level 3 in the Air; Electrostatic Discharge
- EN 61000-4-2: 1995 Level 2 by Contact; Electrostatic Discharge
- EN 61000-4-3: 1996 Level 2; Radiated Field Immunity
- EN 61000-4-4: 1995 Level 2; Electrical Fast Transient
- EN 61000-4-6: 1996 Level 2; Conducted Immunity
- ENV 50204: 1995 Level 2; Radiated Field Immunity

CE



Active Pressure Monitor (APM)

Active Pressure Monitor

The Phoenix Controls Active Pressure Monitor accurately measures the pressure differential between two rooms or spaces in a building where pressurization is critical. Utilizing true differential pressure sensing, it is capable of measuring and alarming to within 0.5% of full scale and displaying the pressure to 0.0001 inches of water gauge (0.0249 Pa). It can meet the stringent requirements of laboratory animal facilities, hospital areas, research facility laboratories and cleanrooms.

Each Active Pressure Monitor consists of a room sensor, a reference space sensor and a room pressure monitor panel.

Optional features include the ability to remotely switch the room pressure alarm set point from a dry contact and to provide flow alarming when used with Phoenix Controls Accel® airflow control valves, verifying both pressure and volumetric flow requirements are being met.

Specifications

Dimensions
Faceplate
9.5" (241.3 mm) W x 5.5" (139.7 mm) H

Accuracy
±0.5% FS Terminal Point (±0.35% FS BFSL)

Stability
< ±1.0% FS per year

Temperature Effects
< ±0.03% FS/°F (.05% FS/°C)

Over-pressure
5 PSIG Proof (34.5 KPa)

Response
< 0.25 seconds for full span input

Standard Range
±0.05" WC (12.45 Pa)

Optional Ranges
- ±0.1" WC (24.9 Pa)
- ±0.2" WC (49.8 Pa)
- ±0.5" WC (124.5 Pa)
- ±1.0" WC (249 Pa)
- ±2.0" WC (498 Pa)
- ±5.0" WC (1245 Pa)

Display
- 4 digit LED
- 0.5" height (12.7 mm)

Analog Output
Field selectable: 4-20 mA, 12 mA at zero pressure
or
0-10 Vdc, 5 Vdc at zero pressure

Alarm Output
SPDT relay

Contact UL/CSA Rating
2.0 A @ 30 volts AC/DC

Alarm Deadband
0.1% FS

Alarm Delay Range
0-30 seconds

Power
22-26 Vac
50/60 Hz

Power Consumption
4.0 VA

Operating Temperature
32-160 °F (0-70 °C)

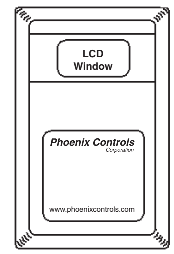
Storage Temperature
-40-180 °F (-40-82 °C)

Weight
2.1 pounds (0.95 Kg)

CE

Feature/Option	APM100	APM100-REM
Faceplates		
Digital Display	✓	✓
Pressure Alarm Status LEDs	✓	✓
Audible Alarm	✓	✓
Mute Button	✓	✓
Flow Caution LED		✓
Monitoring		
Analog Output (4-20 mA or 0-10 Vdc)	✓	✓
SPDT alarm delay	✓	✓
Control		
Adjustable alarm time delay (0-30 seconds)	✓	✓
Field reversible pressurization alarm	✓	✓
Remote reversible pressurization alarm		✓
Remote flow alarm input		✓

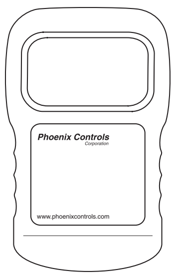
Temperature and Humidity Sensors



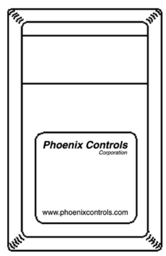
Temperature sensor

Phoenix Controls temperature, humidity and air quality sensors provide a stable, secure environment for those facilities that need it the most, such as hospitals, clean rooms, and laboratory animal facilities. These sensors also simplify room balancing by eliminating the need for a certified person to accompany the balancer during the commissioning process.

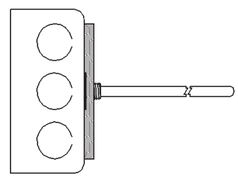
- Teflon-insulated wires ensure resistance to moisture, corrosive elements, and abrasion.
- A three-position test and balance (T&B) switch allows for overrides into full heating or cooling modes, as well as for normal operation.



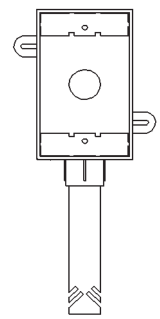
Stat2 sensor (temperature and humidity models available)



Humidity sensor



Duct sensor



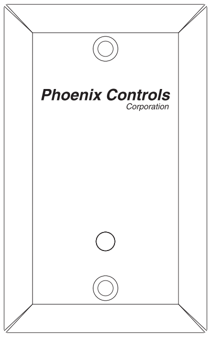
Outside air unit

Specifications

	Temperature		Humidity and Combination		
	Room	Duct	Room	Duct	Outside
Signal	10K, Type 2 thermistor	10K, Type 2 thermistor	4 to 20 mA (output)	4 to 20 mA (output)	4 to 20 mA (output)
Supply Voltage	5 to 25 Vdc (LCD only)	—	15 to 24 Vdc (current or voltage output)	—	—
Power Consumption	< 0.2 VA	—	< 1.1 VA	—	—
Operating Temperature Range	-67 to 302 °F (-55 to 150 °C)	-67 to 302 °F (-55 to 150 °C)	32 to 158 °F (0 to 70 °C)	-10 to 160 °F (-23 to 71 °C)	-10 to 160 °F (-23 to 71 °C)
Environmental Temperature Range	32 to 122 °F (0 to 50 °C)	-40 to 212 °F (-40 to 100 °C)	32 to 122 ºF (0 to 50 ºC)	-22 to 150 ºF (-30 to 70 °C)	-22 to 158 °F (-30 to 70 °C)
Environmental Humidity Range	0 to 95% RH (non-condensing)	0 to 100% RH (non-condensing)	0 to 95% RH (non-condensing)	0 to 100% RH	0 to 100% RH
Housing Material	ABS plastic	Steel	ABS plastic	Weatherproof cast aluminum	Weatherproof cast aluminum
Accuracy	±0.2 °C (0 to 70 °C)	±0.2 °C (0 to 70 °C)	±2% from 15 to 95% RH at 25 °C	±2% from 15 to 95% RH at 25 °C	±2% from 15 to 95% RH at 25 °C
Dissipation Constant	3 mW/C	3 mW/C	—	—	—
Stability	< 0.02 °C/year	< 0.02 °C/year	—	—	—
Reference Resistance	10 kW at 25 °C	10 kW at 25 °C	—	—	—
Sensing Element	Thermistor	Thermistor	Impedance type humidity sensor	—	—
Response Time	—	—	20 seconds for a 63% step	20 seconds for a 63% step	—

CE

Wall Plate Temperature and Humidity Sensors



Wall Plate Temperature and Humidity Sensor

Phoenix Controls wall plate combination temperature and humidity sensor provides a stable, secure environment for facilities that need it the most, such as hospitals, cleanrooms, biocontainment laboratories and vivariums. This sensor is suitable for locations requiring wipedown, washdown or gaseous decontamination, or where flush mount installation is desired.

- Stainless steel, watertight wall plate unit
- Flush mount design
- ±2% relative humidity (RH) accuracy
- Full-range temperature compensation of RH signal
- Choice of humidity outputs (0-10 Vdc or 4-20 mA)

Specifications

	Wall Plate Sensor		Accessories			
	Temperature	**Humidity**	**Current Output Module**	**Resistive Output Module**	**Voltage Output Module**	**Power Supply**
Signal	—	4 to 20 mA (output)	—	—	—	—
Supply Voltage	5 Vdc (provided by VPS)	5 Vdc (provided by VPS)	9 to 36 Vdc, loop powered	10 to 30 Vdc or 17 to 31 Vac	14 to 30 Vdc or 17 to 31 Vac	8 to 24 Vdc or 6 to 24 Vac
Power Consumption	< 1 mA DC maximum	< 1 mA DC maximum	20 mA maximum, loop powered	3 mA DC maximum 0.1 VA AC maximum	3 mA DC maximum 0.1 VA AC maximum	20 mA DC maximum 0.6 VA AC maximum
Operating Temperature Range	-27 to 150 °F (-30 to 70 °C)	—	—	-32 to 140 °F (0 to 60 °C)	—	—
Operating Humidity Range	—	0 to 100% RH (non-condensing)	0 to 95% RH (non-condensing)	—	0 to 95% RH (non-condensing)	—
Environmental Temperature Range	-40 to 176 °F (-40 to 80 °C)	-40 to 176 °F (-40 to 80 °C)	35 to 120 °F (1 to 50 °C)	35 to 120 °F (1 to 50 °C)	35 to 120 °F (1 to 50 °C)	—
Environmental Humidity Range	0 to 100% RH (non-condensing)	0 to 100% RH (non-condensing)	0 to 100% RH	0 to 100% RH	0 to 100% RH	—
Housing Material	304 SS	304 SS	ABS plastic	ABS plastic	ABS plastic	ABS plastic
Material Rating	—	—	UL 94, V-0	UL 94, V-0	UL 94, V-0	UL 94, V-0
RJ-485 Cable Distance	4000 feet (305 meters) to VPS	4000 feet (305 meters) to VPS	100 feet (30.5 meters)	100 feet (30.5 meters)	100 feet (30.5 meters)	—
Accuracy	±0.5 °C, 0 to 49 °C (0.9 °F, 23 to 120 °F)	±2% RH	—	—	—	—
Stability	—	< 0.5% RH/year	—	—	—	—
Sensing Element	Semiconductor band gap, proportional to absolute temperature	Capacitive polymer	—	—	—	—
Response Time	—	60 seconds for a 63% step	—	—	—	—

Table of Contents

6 Standards and Guidelines

This is a compilation of excerpts from applicable laboratory animal facility guidelines in use today. The intent is to provide the owner, engineer and architect an overview of standards and/or guidelines for designing and ventilating laboratory animal facilities. Individuals should consult all relevant local, state and federal building codes to define which standards and guidelines from this section may apply to a particular facility.

General Information

2007 ASHRAE Applications Handbook, p. 14.14

"Laboratory animals must be housed in comfortable, clean, temperature- and humidity-controlled rooms. Animal welfare must be considered in the design; the air-conditioning system must provide the macroenvironment for the animal room and the subsequent effect on the microenvironment in the animal's primary enclosure or cage specified by the facility's veterinarian... Early detailed discussions with the veterinarian concerning airflow patterns, cage layout, and risk assessment help ensure a successful animal room HVAC design. The elimination of research variables (fluctuating temperature and humidity, drafts, and spread of airborne diseases) is another reason for a high-quality air-conditioning system."

2005 ASHRAE Fundamentals Handbook, p. 10.2

"Animal facilities that facilitate good animal care and welfare must be designed considering a wide range of environmental factors beyond thermal conditions. These include space requirements, flooring type, lighting, feed and water requirements, animal handling, and waste management."

CCAC Guide to the Care and Use of Experimental Animals, Section II.A, "Laboratory Animal Facilities: Introduction"

"A laboratory animal facility must facilitate research by minimizing undesirable experimental variables while providing for the physiological, social and behavioral requirements of the animal. Different research projects and/or different species of animals often require differing facilities and environments. To accommodate such needs, an animal facility must have separate areas for carrying out different functions, specialized rooms and equipment, and closely controlled environments.

"Animal facilities providing the appropriate environment are expensive to build. It is, therefore, imperative that every effort be made to ensure that any proposed new facility is programmed, designed, and built to meet the size and scope of current animal use, and yet to be versatile enough to allow flexibility in the years to come."

ILAR *Guide* for the Care and Use of Laboratory Animals, p. 71

"A well-planned, well-designed, well-constructed, and properly maintained facility is an important element of good animal care and use, and it facilitates efficient, economical, and safe operation. The design and size of an animal facility depend on the scope of institutional research activities, the animals to be housed, the physical relationship to the rest of the institution, and the geographic location. Effective planning and design should include input from personnel experienced with animal-facility design and operation and from representative users of the proposed facility. Computational fluid dynamics (CFD) modeling of new facilities and caging might be beneficial (Reynolds and Hughes 1994)."

Research Animals in Healthcare Facilities

CDC Health Care Facility Guidelines for Infection Control, p. 30, Section VI.D
"Ensure proper ventilation through appropriate facility design and location.
"1. Keep animal rooms at negative pressure relative to corridors.
"2. Prevent air in animal rooms from recirculating elsewhere in the health-care facility."

HVAC Systems/Flexibility

CCAC Guide to the Care and Use of Experimental Animals, Section II.E.3, "Holding Rooms;" Section III.A, "Climate Control"
"It is important, when designing holding rooms to consider possible future uses of these facilities. Where animal use has been consistent over the years, it may be acceptable to design all animal rooms for specific species use. However, in many facilities, animal use fluctuates considerably, making flexibility extremely important. A flexible holding room is one which meets the acceptable requirements for housing different species...

"The design of the animal facility should permit adjustment of environmental controls to meet the needs of the species and the experimental protocol. Ideally, each animal room would be controlled independently."

NIH Vivarium Design Policy and Guidelines, pp. B-4, D-15
"A goal of these guidelines is to provide vivarium facilities that are adaptable. The spaces shall be generic with the ability to accommodate changes in function without having to make major changes to the facility. Individually planned, nongeneric, or customized spaces are to be avoided where possible. The vivarium space and its accompanying utility services shall be planned and designed to be adaptable to changes in animal species and research protocol...

"HVAC systems for vivarium facilities must be independent from other building HVAC systems. These systems must maintain a safe and comfortable environment for animals, be adaptable, and be capable of maintaining environmental conditions in any of the holding rooms for any of the species anticipated to be housed in the facility."

Redundancy and Emergency Power

2007 ASHRAE Applications Handbook, p. 14.15
"Conditions in animal rooms must be maintained constant. This may require year-round availability of refrigeration and, in some cases, dual/standby chillers and emergency electrical power for motors and control instrumentation. Storage of critical spare parts is one alternative to installing a standby refrigeration system."

CCAC Guide to the Care and Use of Experimental Animals, Section III.A.1, "Temperature"
"It is essential that emergency equipment be available to maintain environmental temperatures, particularly in rooms housing small laboratory animals, fish, and non-human primates (NHP)."

ILAR *Guide* for the Care and Use of Laboratory Animals, p. 76
"In the event of a partial HVAC system failure, systems should be designed to supply facility needs at a reduced level. It is essential that life-threatening heat accumulation or loss be prevented during mechanical failure. Totally redundant systems are seldom practical or necessary except under special circumstances (as in some biohazard areas)."

NIH Vivarium Design Policy and Guidelines, pp. D-12, D-15 to D-16
"HVAC systems must be both reliable and redundant and operate without interruption. There should be no exceptions...

"Since most animal studies are of long duration, they must be performed under consistent conditions in order to achieve repeatable results. Thus, the failure of the HVAC system is unacceptable. Therefore, the HVAC system must be designed to provide backup in the event of component failure. Central HVAC systems thus should be provided with multiple chillers, pumps, cooling towers, etc. to improve reliability."

Ventilation Rates

2007 ASHRAE Applications Handbook, p. 14.15

"The air-conditioning load and flow rate for an animal room should be determined by the following factors:

- Desired animal microenvironment...
- Species of animal(s)
- Animal population
- Recommended ambient temperature and humidity (Table 1) (NOTE: This table is shown on page 93, the same as Table 2.4 of ILAR.)
- Heat produced by motors on special animal housing units (e.g., laminar flow racks or HEPA-filtered air supply units for ventilated racks)
- Heat generated by the animals (Table 2) (see next page)

"Additional design factors include method of animal cage ventilation; operational use of a fume hood or a biological safety cabinet during procedures such as animal cage cleaning and animal examination; airborne contaminants (generated by animals, bedding, cage cleaning, and room cleaning); and institutional animal care standards (Besch 1980, ILAR 1996). It should be noted that the ambient conditions of the animal room might not reflect the actual conditions within a specific animal cage."

2005 ASHRAE Fundamentals Handbook, p. 10.1

"Generally, a ventilation rate sufficient to remove water vapor adequately controls gases. However, improper air movement patterns, certain waste-handling methods, and special circumstances (e.g., disease outbreak) may indicate that more ventilation is necessary. In many cases, ventilation is not as effective for dust control as for gas control. Alternative dust control strategies may be needed."

CCAC Guide to the Care and Use of Experimental Animals, Section III.A.3, "Ventilation"

"The actual ventilation rate required varies with age, sex, species, stocking density, frequency of cleaning, quality of incoming air, ambient temperature and humidity, and construction of primary and secondary enclosures, among other factors. Draft-free air exchanges in the range of 15-20 per hour are commonly recommended for rooms containing small laboratory animals under conventional housing conditions (Clough, 1984). Achieving these rates does not guarantee adequate ventilation at the cage level, particularly if filter-tops are used (Keller, White, Sneller et al. 1989)."

ILAR *Guide* for the Care and Use of Laboratory Animals, pp. 30-32

"The purposes of ventilation are to supply adequate oxygen; remove thermal loads caused by animal respiration, lights and equipment; dilute gaseous and particulate contaminants; adjust the moisture content of room air; and where appropriate, create static-pressure differentials between adjoining spaces. Establishing a room ventilation rate, however, does not ensure the adequacy of the ventilation of an animal's primary enclosure and hence does not guarantee the quality of the microenvironment...

"The guideline of 10-15 fresh air changes per hour has been used for secondary enclosures for many years and is considered an acceptable general standard. Although it is effective in many animal-housing settings, the guideline does not take into account the range of possible heat loads; the species, size, and number of animals involved; the type of bedding or frequency of cage-changing; the room dimensions; or the efficiency of air distribution from the secondary to the primary enclosure...

"Even though that [heating and cooling load] calculation can be used to determine minimal ventilation needed to prevent heat buildup, other factors—such as odor control, allergen control, particle generation, and control of metabolically generated gases—might necessitate ventilation beyond the calculated minimum.When the calculated minimal required ventilation is substantially less than 10 air changes per hour, lower ventilation rates might be appropriate in the secondary enclosure, provided that they do not result in harmful or unacceptable concentrations of toxic gases, odors, or particles in the primary enclosure. Similarly, when the calculated minimal required ventilation exceeds 15 air changes per hour, provisions should be made for additional ventilation required to address the other factors."

Temperature and Humidity

2007 ASHRAE Applications Handbook, pp. 14.15 to 14.16

"A totally flexible system permits control of the temperature of individual rooms to within ±2°F for any set point in a range of 64 to 85°F. This flexibility requires significant capital expenditure, which can be mitigated by designing the facility for selected species and their specific requirements...

"Air-conditioning systems must remove the sensible and latent heat produced by laboratory animals. The literature concerning the metabolic heat production appears to be divergent, but new data are consistent. Current recommended values are given in Table 2. These values are based on experimental results and the following equation:

ATHG = 2.5M
where
ATHG = average total heat gain, Btu/h per animal
M = metabolic rate of animal, Btu/h per animal = 6.6 $W^{0.75}$
W = weight of animal, lb

Table 2. Heat Generated by Laboratory Animals

	Heat Generation, Btu/h per Normally Active Animal			
Species	Weight, lb	Sensible	Latent	Total
Mouse	0.046	1.11	0.54	1.65
Hamster	0.260	4.02	1.98	6.00
Rat	0.620	7.77	3.83	11.60
Guinea pig	0.900	10.20	5.03	15.20
Rabbit	5.410	39.20	19.30	58.50
Cat	6.610	45.60	22.50	68.10
Nonhuman primate	12.000	71.30	35.10	106.00
Dog	22.700	105.00	56.40	161.00
Dog	50.000	231.00	124.00	355.00

"In the case of animals in confined spaces, the range of daily temperature fluctuations should be kept to a minimum. Relative humidity should also be controlled. ASHRAE *Standard* 62 recommends that the relative humidity in habitable spaces be maintained between 30 and 60% to minimize growth of pathogenic organisms. ILAR (1996) suggests the acceptable range of relative humidity is 30 to 70%...

"If the entire animal facility or extensive portions of it are permanently planned for species with similar requirements, the range of individual adjustments may be reduced. Each animal room or group of rooms serving a common purpose should have separate temperature and humidity controls."

2005 ASHRAE Fundamentals Handbook, p. 10.1

"Acceptable conditions are most commonly established based on temperature because an animal's sensible heat dissipation is largely influenced by the temperature difference between the animal's surface and ambient air.

"With warm or hot ambient temperature, elevated humidity can restrict performance severely."

CCAC Guide to the Care and Use of Experimental Animals, Section III.A.2, "Humidity"

"Most laboratory animals prefer a relative humidity around 50%, but can tolerate a range of 40-70% as long as it remains relatively constant and the temperature range is appropriate (Clough, 1987). Discomfort results when humidity levels adversely affect the animal's ability to maintain thermal homeostasis. In facilities where humidity is difficult to control within an acceptable range, dehumidification or humidification devices may need to be installed.

"Humidity levels can affect experimental results by influencing temperature regulation, animal performance, and disease susceptibility."

ILAR *Guide* for the Care and Use of Laboratory Animals, pp. 29, 32, 75

"Environmental temperature and relative humidity can depend on husbandry and housing design and can differ considerably between primary and secondary enclosures...

"A system should be capable of adjustments in dry-bulb temperatures of ±1°C (±2°F). The relative humidity should generally be maintained within a range of 30-70% throughout the year. Temperature is best regulated by having thermostatic control for each room."

Table 2.4 Recommended Dry-Bulb Temperatures for Common Laboratory Animals

	Dry-Bulb Temperature	
Animal	°C	°F
Mouse, rat, hamster, gerbil, guniea pig	18-26	64-79
Rabbit	16-22	61-72
Cat, dog, nonhuman primate	18-29	64-84
Farm animals and poultry	16-27	61-81

NIH Vivarium Design Policy and Guidelines, pp. D-14 to D-15

Indoor Design Conditions

"The following indoor design conditions shall be used in the design of the animal facilities. Animal-holding areas shall be maintained at the design conditions at all times. Design conditions shall be satisfied under all load conditions between the various holding areas.

General Requirements:		
	Temperature	Humidity
Summer	23° C ±1°C	50% ±5% relative humidity (RH)
Winter	23° C ±1°C	40% ±5% RH

Animal Housing:		
	Temperature	Humidity
Mouse	18°C to 26°C	40-70% RH
Hamster	18°C to 26°C	40-70% RH
Guinea pig	18°C to 26°C	40-70% RH
Rabbit	16°C to 21°C	40-70% RH
Dog	18°C to 29°C	30-70% RH
Nonhuman primate	16°C to 29°C	45-70% RH
Chicken	16°C to 27°C	45-70% RH

"Ideally, all animal-holding rooms shall be capable of housing all species to be housed. The HVAC system must also be capable of maintaining the full range of requirements for all anticipated animal populations."

Air Movement and Distribution

2007 ASHRAE Applications Handbook, pp. 14.16

"Supply air outlets should not cause drafts on research animals. Efficient air distribution for animal rooms is essential. This may be accomplished effectively by supplying air through ceiling outlets and exhausting air at floor level...Supply and exhaust systems should be sized to minimize noise.

A study by Neil and Larsen (1982) showed that predesign evaluation of a full-size mock-up of the animal room and its HVAC system was a cost-effective way to select a system that distributes air to all areas of the animal-holding room. Wier (1983) describes many typical design problems and their resolutions. Room air distribution should be evaluated using ASHRAE *Standard* 113 procedures to evaluate drafts and temperature gradients."

ILAR *Guide* for the Care and Use of Laboratory Animals, pp. 31-32

"The volume and physical characteristics of the air supplied to a room and its diffusion pattern influence the ventilation of an animal's primary enclosure and so are important determinants of its microenvironment. The relationship of the type and location of supply-air diffusers and exhaust vents to the number, arrangement, location, and type of primary enclosures in a room or other secondary enclosure affects how well the primary enclosures are ventilated and should therefore be considered. The use of computer modeling for assessing those factors in relation to heat loading and air diffusion patterns can be helpful in optimizing ventilation of primary and secondary enclosures (for example, Hughes and Reynolds 1995; Reynolds and Hughes 1994)."

NIH Vivarium Design Policy and Guidelines, p. 17

Air Motion Criteria

"Animal facilities shall be designed with special attention to air quality, acoustics, airflow quantities, diffusion characteristics, means of delivery, delivery temperature, air velocity, and air distribution.

- Distribution shall prevent cross contamination between individual spaces, air shall flow from areas of least to areas of higher contamination potential, i.e. from "clean" to "dirty" areas.
- Air supply terminals shall be located at ceiling level or close to ceiling level if located on side walls. Exhaust from animal rooms shall be located near the floor level. It is preferable to have multiple exhaust points in animal rooms.
- Air distribution and diffusion devices shall be selected to minimize temperature differentials in the space. The maximum air velocities in the occupied zone shall not exceed 0.25 m/s at an elevation of 1.8 m.
- In the cage-wash facility, the dirty, clean, and cage-wash equipment, including associated mechanical supporting equipment areas, shall be physically separated from each other, including equipment pits. Canopy exhaust hoods shall be installed for heat-generating cage-wash equipment in both the dirty and the clean side of the facility."

Pressurization

CCAC Guide to the Care and Use of Experimental Animals, Section III.A.3, "Ventilation"

"Differential pressures can be used to inhibit the passage of pathogenic material between rooms. Higher pressures are used in clean areas relative to dirty or bio-hazardous ones, in order to minimize contamination (Hessler and Moreland, 1984). In facilities where containment or exclusion of airborne microorganisms depends in part on differentials in air pressure, inclined manometers or magnahelic gauges can be used to measure the difference between the high and low pressure areas in millimeters of water. Generally, 2.5-5.0 mm (0.1-0.2 in.) differential is maintained (Small, 1983)."

ILAR *Guide* for the Care and Use of Laboratory Animals, p. 76

"Also, consideration should be given to the regulation of air-pressure differentials in surgical, procedural, housing, and service areas. For example, areas for quarantine, housing, and use of animals exposed to hazardous materials and for housing of nonhuman primates should be kept under relative negative pressure, whereas areas for surgery, for clean-equipment storage, and for housing of pathogen-free animals should be kept under relative positive pressure with clean air."

NIH Vivarium Design Policy and Guidelines, pp. D-17 to D-19

Relative Pressurization

"Vivarium spaces must be protected against contamination from outside sources, including particulates brought in from outside in the HVAC airstream. Generally the vivarium facility must remain at a negative air pressure relative to clean corridors and other nonvivarium spaces but positive with respect to the outside environment. Relative pressurization inside the vivarium facility is a series of complex relationships. Some of these relationships may change as research and animal populations change. The HVAC system must be capable of maintaining these relative pressure relationships and capable of adapting as facility utilization changes.

"Clean areas of the facility, including the clean side of cage and rack washing, the clean corridor system, and bedding dispensing, diet, and preparation areas must be positive relative to animal holding areas or soiled areas.

"Animal housing areas generally are negative relative to clean areas and positive relative to service corridor and soiled areas.

"Soiled areas such as the service corridor, the soiled side of cage and rack washing, and decontamination and waste-holding areas must be maintained at a negative pressure relative to the animal rooms.

Some areas have special pressurization requirements and shall be addressed individually.

"Animal-holding areas for transgenic or immunosuppressed populations must be maintained at a positive pressure and may require special filtration of supply air.

"Potentially infectious populations must be maintained at a negative pressure to prevent contagion from migrating to other populations. Depending on the nature of the infectious agents involved in the research, these areas may be required to meet the design criteria for biohazard containment facilities. To maintain these special conditions, anterooms or micro-isolator housing units may be required.

"The pressure relationships for animal care areas including treatment rooms, procedure rooms, necropsy rooms, and surgical areas require investigation by the design team with the facility user to determine project-specific requirements.

"The HVAC system must be adaptable so that pressure relationships can be modified as required over the life of the facility."

Recirculation

CCAC Guide to the Care and Use of Experimental Animals, Section III.A.3, "Ventilation"

"The design of the ventilation system should take energy conservation into account (Besch, 1980). Although total air exchange systems are preferable, they are not always economical, especially in regions experiencing temperature extremes. Recirculating air systems must be equipped with effective filters (and scrubbers, if necessary) to avoid the spread of disease and to remove particulate and gaseous contaminants (e.g., NH_3) (Hessler, 1984)."

ILAR *Guide* for the Care and Use of Laboratory Animals, p. 33

"Caging with forced ventilation that uses filtered room air and other types of special primary enclosures with independent air supplies (i.e., air not drawn from the room) can effectively address the ventilation requirements of animals without the need to ventilate secondary enclosures to the extent that would be needed if there were no independent primary-enclosure ventilation. Nevertheless, a secondary enclosure should be ventilated sufficiently to provide for the heat loads released from its primary enclosures. If the specialized enclosures contain adequate particulate and gaseous filtration to address contamination risks, recycled air may be used in the secondary enclosures...

"The use of recycled air to ventilate animal rooms saves considerable amounts of energy but might entail some risk. Many animal pathogens can be airborne or travel on fomites, such as dust, so exhaust air to be recycled into hearing, ventilation, and air conditioning (HVAC) systems that serve multiple rooms presents a risk of cross contamination. The exhaust air to be recycled should be HEPA-filtered (high-efficiency particulate air-filtered) to remove airborne particles before it is recycled; the extent and efficiency of filtration should be proportional to the estimated risk…The risks in some situations, however, might be too great to consider recycling (e.g., in the case of nonhuman-primate and biohazard areas.)...

"...the use of nonrecycled air is preferred for ventilation of animal use and holding areas."

NIH Vivarium Design Policy and Guidelines, p. D-16

Air Quality
"Recirculation of air in a vivarium is prohibited."

Biohazard Containment

ILAR *Guide* for the Care and Use of Laboratory Animals, pp. 17, 76
"Hazardous agents should be contained within the study environment. Control of airflow (such as through the use of biologic-safety cabinets) that minimizes the escape of contaminants is a primary barrier used in the handling and administration of hazardous agents and the performance of necropsies on contaminated animals (CDC 1995; Kruse and others 1991). Special features of the facility—such as airlocks, negative air pressure, air filters, and redundant mechanical equipment with automatic switching—are secondary barriers aimed at preventing accidental release of hazards outside the facility and work environment...

"Containment requires the use of biologic-safety cabinets and exhausted airlocks or other means, some of which are described in Chapter 1 of the ILAR Guide."

NIH Vivarium Design Policy and Guidelines, p. C-5
"For specific requirements refer to the Center for Disease Control and Prevention (CDC) and the NIH guidelines for biosafety level (BL) planning and design. As a minimum, all laboratories at the NIH are designed as BL2 facilities."

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Industry Organization/Affiliation Web Sites

- American Association for Laboratory Animal Science, (AALAS) — http://www.aalas.org/index.aspx
- American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) — http://www.ashrae.org
- Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC) — http://www.aaalac.org
- Canadian Association for Laboratory Animal Science (CALAS) — http://www.calas-acsal.org
- Canadian Council on Animal Care (CCAC) — http://www.ccac.ca
- Federation of European Laboratory Animal Science Associations (FELASA) — http://www.felasa.eu/index.htm
- International Council for Laboratory Animal Science (ICLAS) — http://www.iclas.org
- Institute for Laboratory Animal Research (ILAR) — http://dels.nas.edu/ilar_n/ilarhome/
- Laboratory Animal Management Association (LAMA) — http://www.lama-online.org
- Laboratory Animal Science Association (LASA) — http://www.lasa.co.uk
- National Institutes of Health (NIH) — http://www.nih.gov

Guide for the Care and Use of Laboratory Animals

The full text can be viewed at http://www.nap.edu/readingroom/books/labrats.

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