Cage Rack Ventilation Options for Laboratory Animal Facilities

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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 animals' rooms was often achieved through screened windows and doors and was enhanced by portable fans in the more elaborate facilities.

The care and use of rodents in laboratory animal facilities is a significant growth area today. The number of mice housed in research buildings alone is on course to exceed 100 million by the year 2010. This kind of growth is placing higher demands on architects and engineers hired to design facilities that house rodents. In addition, it has spawned creative methods for alleviating some of the issues and stressors with the ever-increasing animal densities in rodent holding rooms.

Ventilated caging systems are among the methods being used today to increase the number of animals per room. Ventilated cages provide better environments for animals than the static (non-ventilated) cages.

Since their introduction in the late 1970s, ventilated cage racks have grown in popularity, partly because holding room populations can be increased dramatically with these housing systems. Through most of the 90s, the typical method for ventilating cages was achieved using two rack fans, one supply and one exhaust. The supply fan draws room air and HEPA filters it before delivering it to the cages via a rack ducting system. The rack exhaust fan pulls dirty cage air through a HEPA filter and exhausts it back into the room. There are many disadvantages to this method, such as increased cooling requirements, noise, vibration, and increased operating costs. However, one of the greatest concerns is the undesirable environmental issues for workers exposed to volatile irritants in holding rooms.

For this reason, 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 of these attempts have resulted in serious containment issues and environmental instability due to poor rack connections. Designing rack connections requires a thorough understanding of the ventilated rack flow control strategies and static pressure requirements to avoid these problems. 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.

The purpose of this white paper is to discuss the different ventilation options that are available for animal holding rooms, along with the advantages and disadvantages of each.

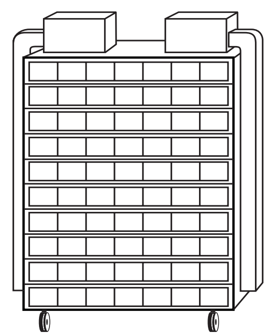

Figure 1. Animal cage rack.

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Types of Cage Environments

The cage is the animal's primary or micro-environment. According to the *Guide for the Care and Use of Laboratory Animals* (the *Guide*), published by the Institute of Laboratory Animal Research (ILAR), 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* micro-environments, because air exchange is minimal (reportedly less than 1 ACH). The cages are kept on shelves in rooms with air change rates ranging from 10 to 15 ACH 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, animal stress, 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.

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

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

Ventilated Caging Systems

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 (85 m^3/hr) 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.

Photo courtesy of Alternative Design, Siloam Springs, AR

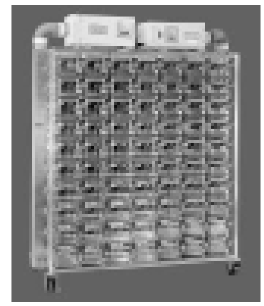

Photo courtesy of Allentown Caging Equipment Co., Allentown, NJ

Figure 3. Examples of ventilated cage racks for rodents.

Key Considerations for 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 (85 m^3/hr) 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. In a holding room, the room air is typically close to the temperature and humidity levels desired for cages. Using the building's central system as the source for supplying air to the ventilated racks requires additional redundancy and environmental controls, resulting in higher costs.
6. High performance, pressure-independent flow controls have been more effective than dampers and flow or pressure measuring devices for connecting racks to the building system.

Ventilation Options for Rodent Holding Rooms

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 pre- and 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.

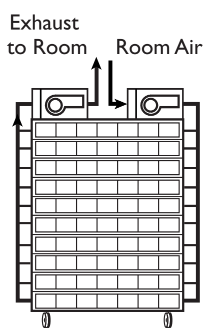

Figure 4. Option #1: Room air with rack supply and exhaust fans. Each fan includes a HEPA filter.

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.
- Temperature and humidity control is simple.

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.
  - Emergency power may be required for the fans.
- Noisy holding rooms. Each room usually includes 4-9 racks, requiring 8-18 fans. Since sound increases by 3 dB 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 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. Attempts to directly connect the rack exhaust to the building prior to the development of thimbles were very problematic because building duct pressure fluctuations created frequent imbalances in the flow, destabilizing the animal's environment.

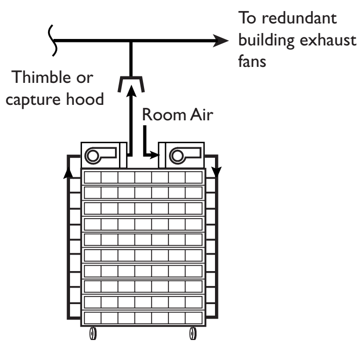

Figure 5. Option #2: Room air with rack supply fan, exhaust fan and thimble.

Advantages:

- Removes volatile irritants from rooms.
- A properly designed and commissioned thimble application solves the pressure fluctuation problems. (Options #3 and 4 also solve these problems.)
- Ventilation devices are isolated from the building's mechanical systems.

Disadvantages:

- Most expensive first and operating costs.
  - This option includes the two rack fans at a cost of typically US $1500 or more per fan, plus the costs of thimble/capture hoods and manifolded ductwork.
  - Balancing the airflow of the pressure dependent devices (manual dampers or blast gates) at each rack drop is difficult.
  - 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.
  - Emergency power may be required for each fan.
  - Rooms require many wash-down duplex outlets.
  - 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 macro- and micro-environmental containment.
- 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.

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

Photos courtesy of Allentown Caging Equiment Company, Allentown, NJ

Figure 6. An example of option #2 installed in a laboratory.

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

The exhaust side of ventilated racks is the more advantageous of the two sides to connect to the building ventilation system. As shown in Figure 8, this approach greatly improves the room's air quality, energy conservation and acoustics.

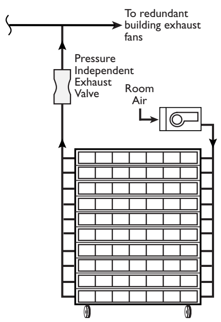

Figure 7. Option #3: Room air with rack supply fan; rack exhaust connected directly to building.

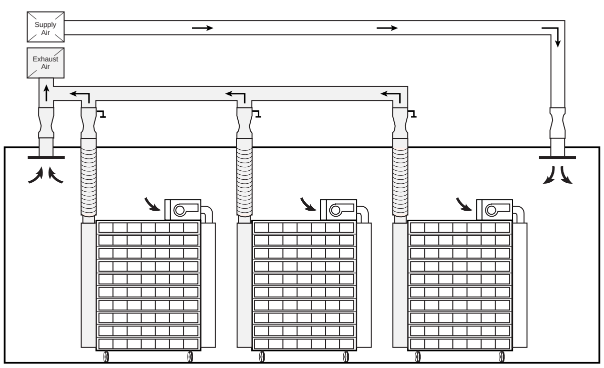

Figure 8. Supply and exhaust airflow pattern for option #3.

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 from the building system easier 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 reduced, decreasing 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. Reduces the need to clean fans, filters, cords, dampers or thimbles in the room during the decontamination process.
- Macro- and micro-environmental improvements. 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.

Pressure independent valves provide a simple and reliable method to make this connection directly, without the need for a thimble or exhaust fan/filter unit. These pressure independent valves maintain a fixed flow of air by adjusting to changes in static pressure. One example of a pressure-independent controller consists of a cone with a staged spring inside. This cone/spring assembly rests on a shaft mounted inside the valve's body. By design, the cone works with the shape of the valve to maintain air volume at a specific setpoint. When there is low static pressure, less force is applied to the cone, which causes the spring within the cone to expand (see Figure 9). As static pressure increases the force on the cone, this causes the spring to compress and moves the cone into venturi to maintain the set flow (see Figure 10).

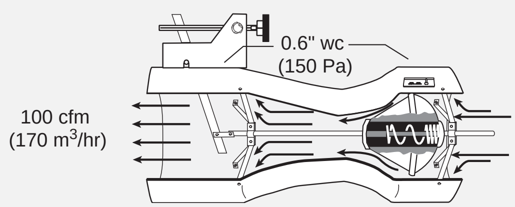

Figure 9. The effect of low static pressure on the cone and spring assembly inside a valve.

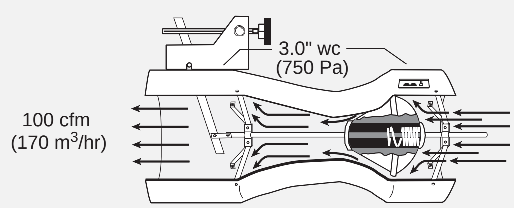

Figure 10. The effect of increased static pressure on the cone and spring assembly.

Disdvantages:

- One fan is still on the rack in the room.
  - These fans are costly, typically US $1500 or more each.
  - Fans generate heat, which increases the room's cooling requirements.
  - Rack fans require maintenance.
  - Emergency power may be required for the fans.
  - The room requires many wash-down duplex outlets to keep the racks ventilated.
  - Fans create more noise in the holding room.
  - Fans vibrate.
  - Removing fans from the racks is cumbersome.
- 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

Figure 11. An example of option #3 installed in a laboratory.

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. Inadequate filtration will cause the exhaust system components, such as turning vanes, sensing probes and fan blades, to accumulate dust, reducing the ventilation system's effectiveness and its capacity to maintain a safe and stable environment.

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, potentially resulting 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).

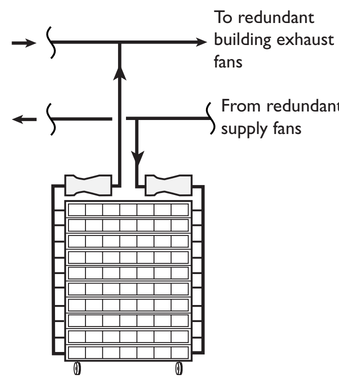

Figure 12. Option #4: Direct connect rack supply and exhaust to building systems.

Advantages of Option #4 over Option #3:

- **Less complicated** 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.
- The temperature and humidity control strategy for conditioned supply air can be complicated and very costly.

A Review of Supply Air Control Alternatives for Option #4

There are two design methods for Option #4: the room supply fan and the dual supply air system.

Option #4 with Room Supply Fan

Although it appears from Figure 13 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 pre- and 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.

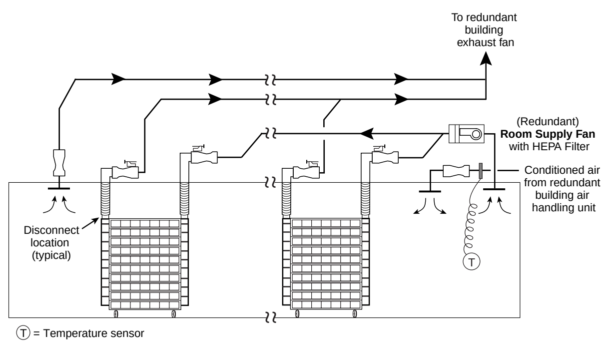

Figure 13. Option #4 with room supply fan.

Advantages:

- Drawing room air into the cages through a HEPA filter with a room supply fan is far simpler, more stable, and less expensive than using a dual supply air system. The room supply fan relies on the room temperature being controlled to a setpoint that is 2-3°F (1-2°C) cooler than the desired cage entering air temperature. Most personnel are comfortable working in that environment.
- Using conditioned room air with a room supply fan virtually eliminates overheating situations because room alarms are more reliable than a mixed temperature rack exhaust sensor as an early warning system.

  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.
- Using a *room supply fan* with HEPA filters that continuously remove air impurities closer to the animals results in a lower particle count in the room and cages.
- 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 overcoming additional static pressure from zone HEPA filters in a central system more effectively. Preventative maintenance (standard intervals for replacing pre-filters) and pressure alarms address loaded filters.

Disadvantages:

- Does not provide the owner the flexibility to control the animal cage environment independently from the room environment.
- Additional costs (capital and operating) for the room supply fan/filter and ductwork.

Most rodent holding rooms today are controlled to a room temperature of 70-73°F (21-23°C), which suits most personnel. Due to the introduction of fan heat, the cage air 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.

Option #4 with Dual Supply Air System

The other method, called the *dual supply air system* (see Figure 14), 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 in the next section, "Critical Issues for Dual Supply Air Systems."

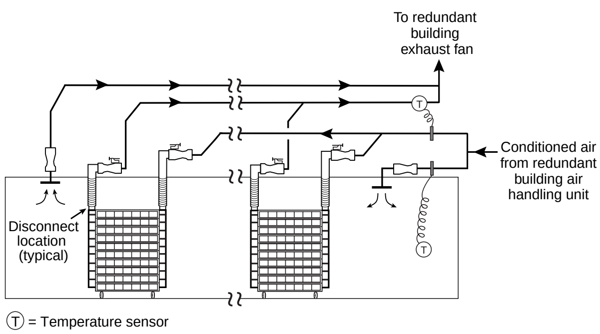

Figure 14. Option #4 with dual supply air system.

Advantages:

- Provides the owner the flexibility to control the animal cage environment independently from the room environment.
- Reduces capital and operating costs for fan systems.

Disadvantages:

- Drawing room air through a HEPA filter using a dual supply air system is more complicated, less stable, and more expensive than using a room supply fan.
- Overheating can occur because the mixed temperature rack exhaust sensor is less reliable than a room alarm as an early warning system. The temperature is not buffered when the air enters the cages directly from the dual supply air system.
- The static pressure from the zone HEPA filters increases in a centralized system.
- Contamination can occur because the HEPA filters are located farther away from the animals.
- Increases the cost for additional environmental control loops.

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 macro-environment 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

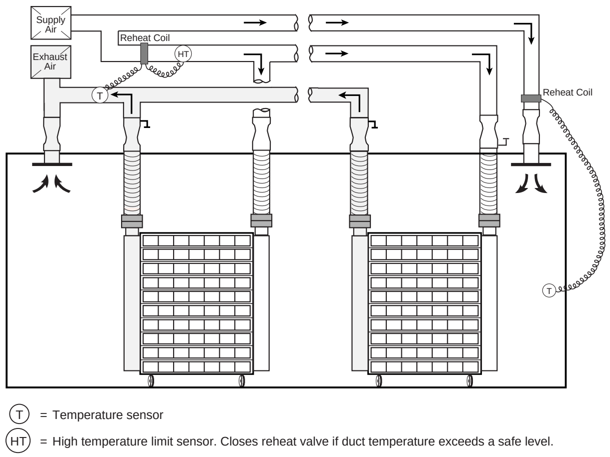

Figure 15. Dual supply air system. Sensing and controlling cage temperature is not as simple as it may appear. Cage rack exhaust is a blended airflow, often with less than 50% cage air, complicating the temperature control and alarming.

and valves, dual humidifiers and dual temperature control loops with dual sensors.

3. *Sensing for and controlling of the environmental control loop for the cage environment*

   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.

   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.

   Figure 15 shows one option for temperature control placement. While tuning and long-term stability may still be an issue, this option does provide aggregate sensing of all cages.

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 setpoint. 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.

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.

6. *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.

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 (for example, Techniplast). These racks may be outside the flow ranges of the available pressure independent control devices.These situations may require a different flow strategy, normally by using multiple racks per valve as shown in Figure 17 or with either Option #2 or 3 discussed earlier. The airflow on the exhaust side of these smaller racks is still high enough to control one rack per 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 are shown in Figure 16. These load simulators 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, these devices generate the same static load to the duct system as the connected racks generate.

Load simulators may not be required on systems that are controlled using one pressure independent control valve per ventilated rack, because the valves compensate for pressure changes automatically.

The system shown in Figure 17 requires manual dampers for balancing flows to each rack. The greatest disadvantages of this approach are balancing at start-up and the system imbalance when someone decides to

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

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

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

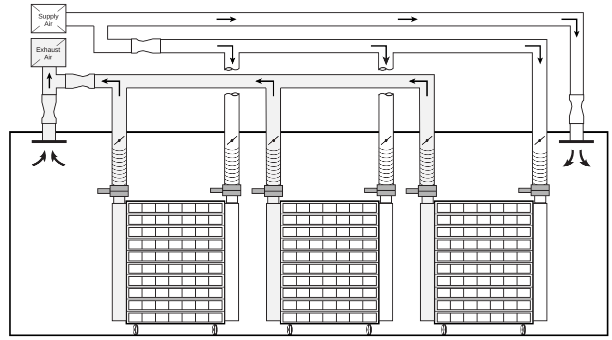

Figure 17. A manifolded system with multiple racks per airflow valve. This method requires additional balancing and possibly load simulators for each drop to the racks.

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 m^3/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.

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.

Summary

Cage racks have grown in popularity since introduced in the 1970s because these allow more animals to be housed in holding rooms. As these populations have grown, so has the need to ensure a safe, comfortable environment for laboratory workers and animals. Quiet ventilation systems that deliver clean, conditioned air to the cages and pull cage exhaust air out of the holding rooms are critical in creating safe, comfortable environments in laboratories.

There are four common ventilation methods for cage racks:

1. Circulating air with rack supply and exhaust fans. The supply fan ventilates the cages by drawing air through pre- and HEPA filters. Rack exhaust fans also have HEPA filters to allow the blower to pull potentially contaminated air from the cages and return clean air to the holding room.
2. Circulating air with rack supply and exhaust fans, but unlike option 1, the exhaust is channeled through a duct to the building exhaust system by a thimble or capture hood.
3. Drawing air into a room through a rack supply fan and pulling contaminated air out of the cages with rack exhaust fans connected directly to the building.
4. Connecting rack supply and exhaust fans directly to the building system. Two design alternatives are available for this option: the room supply fan method and the dual supply air system method.

When designing and selecting ventilation systems for holding rooms that use dual supply air systems, a wide range of critical issues must be addressed. These include:

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

Airflow for cage racks requiring less than 30 CFM (50 m^3/hr) is accomplished by either using multiple racks per valve or ventilation options #2 or #3 mentioned earlier. Single-sided racks are often used in these systems. Although load simulators are often used at each flex drop to the racks when valves are ducted to multiple cages, these are not required on systems controlled with one cage rack valve per ventilated rack.

All rack manufacturers' airflow schematics and requirements vary. Engineers designing duct and airflow control systems for connection to ventilated cage racks must obtain the following critical data from manufacturers of caging systems:

1. Airflow requirements for the rack supply and exhaust.
2. Accuracy requirements for the rack supply and exhaust.
3. Static presure drop required for the rack supply and exhaust.

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