Innovative Design Strategies for Vivarium HVAC Systems

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On the surface, vivariums housing rodents are very similar in function, use, and frankly, design. Generally, they include holding rooms, procedure rooms, cage washing facilities, necropsy, and various other support spaces. Likewise, heating, ventilating and air conditioning (HVAC) systems serving these spaces can also be fairly typical. For these facilities, high ventilation air change rates are maintained by virtually constant volume systems with multiple venturi air valves maintaining supply, exhaust, and cage exhaust air flow to each space. This, in turn, maintains environmental conditions, removes odors, and maintains proper pressurization. These standard features may lead one to believe that HVAC design must be standardized or unimaginative. However, this is not the case. Many unique and innovative techniques can be employed to get the most out of a facility's HVAC system safely and without excessive first cost.

Case Study
A recently completed project, a pediatrics research center in Atlanta, Georgia, falls within what can be considered a typical animal facility. The project was a 150,000 square foot building with a clinic, four floors of research space, and a 13,000 squarefoot vivarium. The schedule was built on a "fast-track" with design and construction completed within 18 months. The vivarium includes 15 holding rooms with a total of 44 cage racks, procedure rooms, necropsy, cage washing, feed and bedding storage, and support space. The HVAC system serving the facility is 100% outside air variable volume system that is passed through an energy recovery system. Exhaust from vivarium spaces is exhausted directly to the outside and does not pass through the energy recovery wheel. Dedicated supply and exhaust air valves that maintain minimum air change rates and space temperature serve each room. Holding rooms are provided with an additional air valve to maintain proper exhaust airflow through ventilated cage racks. The following are some techniques used on this project to reduce project costs, including capital cost, maintenance cost and long term energy costs, while meeting the owner's criteria and expectations.

Keep Down the Air Change Rate
The amount of air required to serve an animal facility is almost always determined by the air change rate required in the spaces rather than cooling load or exhaust requirements. A minimum air change rate of 10-15 air changes per hour for rodent holding rooms is well documented in ASHRAE Applications-2003 Chapter 14 Laboratories, and Guide for the Care and Use of Laboratory Animals but are they

always required? The standard air change rate of 10-15 ACH became a standard when animals were typically housed in open cages. The purpose of the high air change rate was to reduce offensive odors from the animals and their bedding. Modern housing using micro-isolator cages is now a common method. The use of ventilated cage racks, where exhaust and perhaps supply air are ducted directly to each isolator from the building HVAC system, provides clean environments for the animals and greatly reduces odors in the holding rooms. Therefore, in a space with ventilated micro-isolator racks, six to eight air changes may be a more appropriate number. The same may be true with a holding room that is not currently in use. Reducing the air change rate reduces energy usage by lowering fan horsepower. More importantly, energy usage is reduced by lowering the cooling, heating, and reheating requirements. There are many methods of modulating the air change rate through the building automation system, but how can a researcher, who may not be an HVAC expert, be confident that the correct air flow and air change rate are always provided? For this project, a relatively simple and inexpensive solution was engineered. A keyed switch was specified for each holding room, located within the secure area (Figure1). When the switch is unlocked, the user has the capability of switching the space from a high air change rate to a low air change rate, and vice versa. The space is served with two-position air valves, which upon signal from the switch, seamlessly position the air change rate from the high to low setting. Use of this simple system will save thousands of dollars in energy costs each year.

Reduce the Number of Air Valves

A typical modern holding room has multiple ventilated cage racks, each requiring a connection to the building exhaust system. Not all connections are used at all times. A room may be operating at less than capacity or a rack may have been removed for cleaning. In order to maintain constant flow through the rack and its individual isolators, each rack could be connected to the exhaust system individually with its own dedicated air valve. A second approach would be to purchase racks with an integral exhaust fan. Having a dedicated air valve for each rack or a dedicated integral fan are both costly solutions. On this project, a single air valve was used to serve multiple cage racks in an individual holding room. To compensate for various cage configurations, an iris type manual balancing damper was provided in the space at each cage exhaust drop (Figure 2). This damper is calibrated at two different positions, one for a rack connected and one without. When the cage rack is disconnected, the damper is simply adjusted to the “Rack Disconnected” position, which simulates the pressure drop associated with the rack, maintaining the correct flow in the remaining racks. In this manner, 29 air valves were eliminated from the project at an estimated first cost savings of $29,000. In addition, there are fewer valves to locate in an already crowded ceiling plenum, and these eliminated valves will reduce project maintenance costs.

Locating the Returns

Traditionally, animal holding rooms were designed with low exhaust grilles near the floor. The reasoning was that ammonia, from animal urine, is heavier than air and would be better removed from the space from grilles located near the floor. The disadvantage of this approach is that the low exhaust adds construction cost. The most obvious costs are for the extra ductwork and chases but the most significant extra cost is the affect that the chases have on space layouts and building efficiency. For our project, as is now common design practice, we used high devices including a general exhaust grille and direct cage rack connections. This approach, which has been verified by computational fluid dynamics modeling to be effective, resulted in a lower first cost.

Remember the Maintenance Personnel!
Even the most perfectly designed and installed system will require periodic maintenance. Because it is disruptive to the staff and increases maintenance time and cost, it is undesirable for maintenance personnel to enter the actual research or animal holding spaces. Therefore, it is critical to keep air valves, plumbing valves, and equipment requiring maintenance outside of these spaces.

An interstitial space located above the occupied space is the least intrusive design approach. Either a catwalk system or a true full interstitial floor will allow all devices requiring maintenance to be located above the space. With this approach, maintenance personnel intrusion into the facility is limited to changing light bulbs. However, not all building types and project budgets can support this method. An alternative idea is to design the HVAC and plumbing systems so that all the equipment is located in the corridors. With this approach, it is important for the design team to work together early in the design phase to ensure that adequate ceiling plenum and corridor space.
For this project, the design included “extra” ductwork and first cost to locate the devices in the corridor. By doing so, we achieved the goal of locating mechanical equipment outside of animal holding and procedure rooms, minimizing future maintenance disruptions while maximizing productivity.

Don’t Forget Cage Washing
Perhaps one of the most overlooked areas of an animal facility is the cage washing facilities. The exhaust from canopy hoods and the equipment itself (tunnel washers, cage washers, sterilizers) has the potential to be a significant problem in a poorly designed facility. Exhaust from this apparatus is generally hot and humid (180°F and 100% relative humidity). If this exhaust air stream is mixed with the relatively cool (75°F and 50% relative humidity) exhaust air stream, water vapor will condense out of the air. If not handled properly by the HVAC system, this water may cause ductwork to corrode or leak out of ductwork into occupied spaces. A possible solution is to isolate this exhaust with a dedicated exhaust system. If the hot, humid air never mixes with cooler air, the amount of condensation in the exhaust ductwork is reduced. However, adding a dedicated exhaust system is not only costly, but it also takes up valuable building area that could be used, instead, for program space. An alternative, economical solution employed on this project was to recognize that condensation will occur where air streams mix and to manage where and how the water is removed from the ductwork system. By simply sloping stainless steel ducts to specific points, paying careful attention to the seams and joints, and providing drains at low areas, the condensation is removed from the ductwork system without damage to the ductwork or the facility (Figures 3 and 4).

Conclusion

As an Owner or User, working with the designer to understand what HVAC systems can and cannot do is the first step in identifying what types of systems are most appropriate for the facility. When approaching either a renovation to or construction of a new animal facility, the design team must work with the Owner and Users early in the programming and design phases to determine the project requirements and constraints. Issues Owners and Users should explore include: air change requirements, air distribution concepts, operational requirements, anticipated loading, and maintenance procedures. When these issues are identified early, it is possible to break away from traditional design strategies to provide a facility that is both economical from a first and life cycle cost standpoint while meeting both the Owner's and Users' needs.

References

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