HVAC for Laboratory Animals

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Scientists and researchers use laboratory animals to investigate biological processes in humans and animals; to study the causes of diseases; to test drugs, vaccines and surgical techniques; and to evaluate the safety of pesticides, cosmetics and other products.

Many animals function essentially like humans and thus provide the best models for experiments on fundamental processes such as breathing, eating and digesting food and reproducing. Some animals suffer from the same diseases as humans do, with immune systems that respond similarly to disease-causing agents such as viruses and bacteria. Animals also carry a number of genes that are identical to human genes with information for similar traits. Given the similarities, scientists have been able to learn much about the human body by studying animals.

Though animal research is vital to the discovery of new life saving medicines, it is the moral and legal responsibility of all researchers and research organizations to treat the animals with the highest possible care and sympathy before, during and after the research.

The animals used in research must be of a good breed. To know the exact effect of any drug, the research animal should be of normal health, free from stress, free from any disease or infection and should have a stable metabolism rate. Proper HVAC conditions play a major role in maintaining all the above parameters. The animal is healthy when the environmental conditions are close to its normal habitat. Abnormal variation in temperature and humidity may change the animal's metabolism rate and insulin level affecting the amount of food consumption and the weight of the animal. It can also cause stress in the animal and an improper HVAC system can cause the spread of infection through air-borne contamination. This may prove to be very costly as, generally, the required quality breed is developed specially for different experiments. If the breed is found to be infected, when it is ready for research, a lot of time and money is wasted.

In addition to perfect animal care, other aspects such as safety and health of the caretaking personnel and protection of the surrounding environment outside the animal house are equally important. Close exposure of the animal caretaker with laboratory animals can create health hazard for both. Potentially harmful allergic particles may be hazardous for the caretaking personnel and also any infection in caretaking personnel may be passed on to a healthy animal. During certain experiments, the animal colonies may be exposed to dangerous viruses. The air exhausted from such an area without proper

About the Author

Kamalesh Mehta is a mechanical engineer with 25 years experience in HVAC. He founded his company in 1987 and prior to that worked for six years with other companies. Eight years ago, after some research and study, he started manufacturing laboratory equipment that functioned on basic HVAC principles. IVC systems for laboratory animals is one such product. He is an active member of ISHRAE and ASHRAE, past-president of ISHRAE Ahmedabad chapter and presently secretary of ASHRAE W.I. Chapter.

treatment may cause serious biological hazards to the environment and lives around the animal quarters.

Great care should be taken and deep logic should be applied while designing the HVAC system for an animal house to protect the animals, personnel and surrounding environment. Sufficient feedback should be obtained from the animal researcher while designing the HVAC system, as each species of animal has a specific range of preferred environment. It is important to provide the animals, preferred environmental conditions for their survival and reproduction.

Animal comfort conditions consist of many factors such as space requirements, lighting level, noise level and HVAC conditions such as temperature, humidity, cleanliness and velocity of air within the cage. HVAC conditions required are very important and also difficult to maintain, as they tend to vary with the variation in ambient conditions and such other factors.

Basic Design Parameters for HVAC of Animal Quarters

HVAC design for an animal house depends upon many factors such as application, type of animal to be housed, number of animals, kind of experiments in the room, etc. However, taking a broad view, the following factors should be considered while designing the HVAC system.

- **Temperature and humidity range**

Table 1 furnishes some data on the temperature, humidity and air changes recommended by international organisations.

Though the recommended range of temperature and humidity is reasonably wide, it is important that the temperature and humidity is maintained constant. Large variation in temperature or humidity even within the range may cause stress to an animal.

The preferred range of temperature and humidity might be different for commonly used laboratory animals such as mice, rats, hamsters, guinea pigs, rabbits, cats, dogs, primates, etc. Also, there could be a very special requirement for specific species of animal such as nude mice (hairless mice). Necessary housing data should be gathered from the users and guidelines should be referred for recommended conditions prior to designing the system. It would be ideal to allow some flexibility for expected future changes according to experimental requirements.

- **Particulate level**

Allowable particulate level may vary for different zones such as quarantine room, breeding area, experimental area, clean corridor, service corridor (dirty corridor), wash room, autoclave loading room, autoclave exit, husk disposal area, feed storage area, feed preparation area, husk storage area, etc. Filtration system should be designed to meet the allowable particulate level.

Table - 1
Temperature, RH & Minimum ACH recommended by Institute of Laboratory Animal Resources (ILAR) and Canadian Council on Animal Care (CCAC)

Species	Temperature °F (°C)		Relative Humidity (%)		Minimum Room Air Exchange Rate (ACH)	
	ILAR*	CCAC**	ILAR	CCAC	ILAR	CCAC
Mouse	64.4 - 78.8 (18 - 26)	71.6 - 77.0 (22 - 25)	40 - 70	50 - 70	15	8 - 12
Rat	64.4 - 78.8 (18 - 26)	68.0 - 77.0 (20 - 25)	40 - 70	50 - 55	15	10 - 20
Hamster	64.4 - 78.8 (18 - 26)	69.8 - 75.2 (21 - 24)	40 - 70	45 - 65	15	6 - 10
Guinea pig	64.4 - 78.8 (18 - 26)	64.4 - 71.6 (18 - 22)	40 - 70	50 - 60	15	4 - 8
Rabbit	60.8 - 69.8 (16 - 21)	60.8 - 71.6 (16 - 22)	40 - 60	40 - 50	10	10 - 20
Cat	64.4 - 84.2 (18 - 29)	68.0 - 71.6 (20 - 22)	30 - 70	45 - 60	10	10 - 18
Dog	64.4 - 84.2 (18 - 29)	64.4 - 69.8 (18 - 21)	30 - 70	45 - 55	10	8 - 12
Nonhuman primate	64.4 - 84.2 (18 - 29)	69.8 - 78.8 (21 - 26)	30 - 70	45 - 60	10 - 15	12 - 16
Chicken	60.8 - 80.6 (16 - 27)	64.4 - 71.6 (18 - 22)	45 - 70	45 - 70	10 - 15	5 - 15

- **Ventilation rate**

A large colony of animals housed in an animal room generate considerable amount of toxic gases such as ammonia and carbon dioxide. Sufficient air change rate should be provided to evacuate the toxic gases and odor from the animal room. Due to the mixing of such toxic gases, recirculation of air is generally not recommended unless a special kind of caging system is used to ensure clean air supply to the cages.

- **Heat produced by animals**

The heat generation values furnished in *Table 2* are

Table 2 : Heat Generated by Laboratory Animals

Species	Mass,Kg.	Heat Generation, W per Normally Active Animal		
		Sensible	Latent	Total
Mouse	0.021	0.325	0.158	0.484
Hamster	0.118	1.18	0.58	1.76
Rat	0.28	2.28	1.12	3.40
Guinea pig	0.41	2.99	1.47	4.45
Rabbit	2.45	11.5	5.66	17.1
Cat	3.00	13.4	6.59	20.0
Nonhuman primate	5.44	20.9	10.3	31.1
Dog	10.3	30.8	16.5	47.2
Dog	22.7	67.7	36.3	104.0

Reference: ASHRAE Handbook 2003, Ch.14

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based on the following equation derived from experimental results. The formula may be useful when heat generation data is not available for the animals to be housed.

ATHG = 2.5M

where

ATHG = average total heat gain, W per animal

M = metabolic rate of animal, W per animal = $3.5W^{0.75}$

W = weight of animal, kg.

- **Room air velocity**

Air draft over the animal body is one of the factors affecting the comfort level of the animal. Exact data for a comfortable limit of air draft for laboratory animal is not available. However, it is recommended that the air velocity level should be below 0.3 m/sec (at the cage level). Table 1 provides the minimum room air exchange rate.

- **Noise level**

The HVAC system should not become a source of noise which may disturb animal comfort. Though the allowable range of noise level varies from 40 to 70 dBA, it is recommended that the noise level be maintained between 40 to 50 dBA, and a higher noise level is permitted only during particular activities of an animal.

- **Segregation of areas**

Segregation of areas is one of the most important factors to maintain the desired bio-safety level according to requirement. There may be very high biological hazards in certain experiment areas. At the same time, certain areas such as an immuno-compromised animal room may house very delicate animals. Great care must be taken in segregating the HVAC system for all such areas. A considerable amount of time and money could be wasted if any biological contamination is spread from one area to the other.

- **Room pressurization**

Room pressurization plays a major role in maintaining the required biosafety level. Areas such as quarantine and breeding room are recommended to have positive pressure with respect to adjoining experiment rooms to protect fresh / healthy animals from the infection of an animal under experiment.

- **Return and exhaust air filtration**

In addition to the toxic gases, a considerable amount of solid biological particles such as allergens (fur, dander, etc.), bedding material dust, animal feed dust, etc. get mixed up with room air. These particles may cause a biological hazard to surrounding areas if not arrested carefully before discharge. The solid particles may also settle in the return air / exhaust ducts and can sometimes create serious hazards. It is ideal to introduce proper filtration of return / exhaust air right before it leaves the room.

- **Stability**

As explained in previous paragraphs, an abnormal variation in temperature and humidity may affect the biological status of some animals and such animal may not be valid for experimentation. The room conditions must therefore be stable irrespective of the changes in ambient conditions.

- **Reliability and redundancy**

The HVAC system plays a major role in maintaining the quality of animals and their biosafety level. Even a short-time failure of HVAC system may highly disturb the biosafety levels and cause stresses to the animals. It may be very difficult to regain the ideal situation once the biosafety is disturbed. The HVAC system should therefore be fail safe with necessary alarm systems against failure and sufficient standby arrangements.

- **Equipment and maintenance locations**

Equipment such as air handling units are the accumulation points for contamination. The location of such equipment should be planned in such a way that they do not disturb the functioning of animal quarters during maintenance or running. Also the exposure of biohazard contamination during maintenance should not contaminate other units or areas.

- **Material, men and animal flow**

It is difficult to maintain the desired particulate level and conditions in animal quarters as the frequent movement of men, material and animals cannot be restricted. The movement flow should be carefully understood while designing the HVAC system.

Recommended Conditions in Various Supporting Areas and Animal Rooms

Quarantine

This is the incoming area of lab animals. The animals are kept here until their health is evaluated and they become familiar with atmospheric conditions. This room is separated from other animal rooms and the temperature and RH is maintained close to the other animal rooms.

Feed storage

This is the incoming and storage area of animal feed. Usually temperature and humidity is controlled in this area to maintain the quality of food.

Bedding material storage

This is incoming and storage area of bedding material such as husk or other similar material. No special temperature or humidity conditions are required to be maintained, however, high humidity should be avoided. Due care should be taken to avoid the spreading of biological contamination present in husk.

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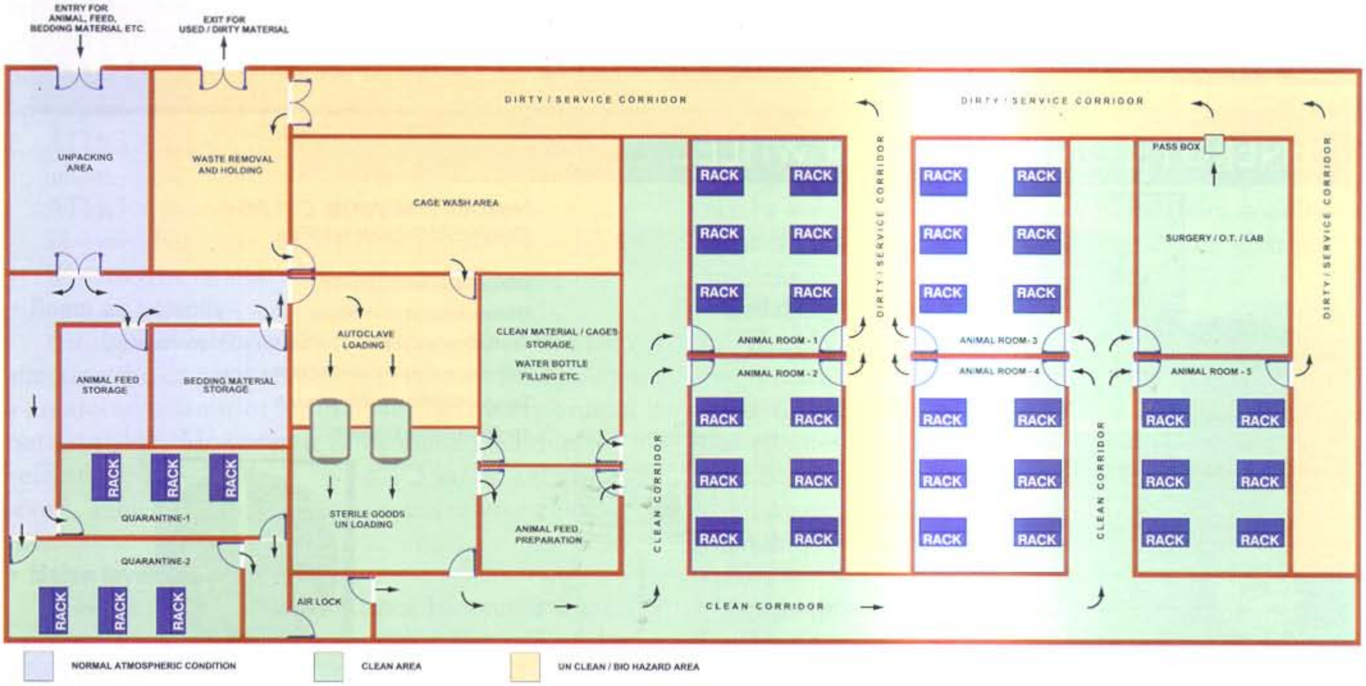

Figure 1 : Schematic diagram of an animal house and flow chart.

Waste holding room

This is the room where used bedding and animal waste is held until it is disposed off. Good ventilation and negative pressure with respect to other rooms is recommended for this area.

Cage wash area

The used cages are washed here and forwarded ahead to autoclave room from this area. Usually provided with some temperature control to minimize heat stress for working personnel. Specific exhaust hoods and separate exhaust ducting should be considered for this space.

Dirty corridor

All dirty / used material and used cages are transported from animal rooms to cage wash or waste discharge area through this corridor. Good ventilation rate with filtered exhaust and negative pressure with respect to animal rooms is recommended for this area. Controlled temperature and RH is recommended for the comfort of working personnel.

Autoclave loading

Material such as washed cages, water bottles, animal feed (raw), bedding material, etc. is loaded in autoclave for sterilization. Room conditions are maintained to avoid stress to working personnel.

Sterile goods unloading / Clean material storage

Material passed through autoclave such as washed cages, water bottles, animal feed, animal bedding, etc. is stored here for a short time until they are forwarded for use through clean corridors. Recommended controlled biosafety level, good ventilation and exhaust close to autoclave outlet to evacuate the heat. Room temperature and RH to be maintained at comfort levels to avoid stress to working personnel. Negative pressure with respect to clean corridor and positive with respect to dirty corridor.

Animal feed preparation (kitchen)

Necessary feed and vitalizer blending is carried out here. Controlled biosafety level, temperature and RH to be maintained.

Clean corridor

Disinfected cages, feed, water, etc. is transferred to animal room through this corridor. Also the transportation of animals from one room to other room is carried out through this corridor. Controlled biosafety level, temperature, RH and positive pressure with respect to animal room is recommended.

Breeding rooms (animal room)

Generally large animal houses have dedicated breeding area to ensure the availability of animal of required age, weight and quality. Controlled biosafety level, temperature, humidity and positive pressure with respect to experimental areas and dirty corridor are recommended.

Experiment rooms (animal room)

These are most sensitive areas of the laboratory. Animals are housed in these rooms during the experiment period. The temperature, RH and controlled biosafety level should be as recommended for the animal

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and type of experiment. All other parameters should be maintained to ensure animal comfort. Negative pressure is maintained with respect to breeding room, recovery room and clean corridors to avoid spreading of pathogens to other areas.

Recovery room (animal room)

The animals planned to be reused after passing through an experiment are housed here until they regain normal healthy conditions. Controlled biosafety level, temperature and RH are maintained. Positive pressure with respect to the experiment room and dirty corridors is recommended.

Surgery rooms (O.T.)

Recommended to be provided with sterile air-conditioning system. Dedicated exhaust system may be provided to exhaust anesthetic gases.

Necropsy lab

Recommended to be installed with special exhaust arrangement on tables to protect working personnel from biological contamination or chemical preservative. For high risk level, Type 3 biosafety cabinets are recommended. Room conditions to be comfortable for working personnel.

Vet's room

Air conditioning of this area is separated from the animal areas. Human comfort conditions to be maintained. Vet's room is connected to clean corridor through air locks.

Some Problems with Traditional Animal Rooms

To achieve the desired results, it is important that the HVAC designer, user and animal facility designer understand each other's requirement at the facility planning stage.

Ideally designed HVAC systems can provide desired room conditions. However, as the cages are open from the top in a traditional caging system, some of the issues remaining unresolved are :

- **Cross infection**

A properly designed HVAC system can protect animals from the contamination outside the room. However, the possibility of an infection from an animal in the same room or from the caretaker can hardly be eliminated.

- **High segmentation**

The animal area is required to be segmented into smaller parts for different kinds of studies to avoid cross infection from an animal of different microbial status.

- **Poor room conditions and poor safety of caretakers**

Toxic and bad odors generated due to animal discharge mixes up with room air and spoils the room environment severely. Also allergens and other biological particles that have escaped from the cage may cause a high health hazard to caretakers and make them prone to respiratory diseases such as asthma.

- **Conditions within the cage**

An ideal HVAC system may provide required room conditions. However, the fact remains that the animals are concerned with the actual condition in the cage and not in the room. Some of the important parameters such as air change rate are not same in the cage as in the room.

- **Poor space utilization**

Considerable free space is required between two cages to allow better ventilation. This reduces the storage capacity of animal room.

- **High investment and high energy cost of HVAC**

Due to high room air change through 100% fresh air, air conditioning load increases considerably causing higher initial cost and running cost of the HVAC system.

Some of the important issues such as cross infection, safety of caretaker and high segmentation could be resolved with the introduction of a slightly modified caging system i.e. filter top cages or microisolator type cages. In this system, the cages are provided with a hepa filter lid. The lid helps in providing an isolated environment within the cage. However, due to the high resistance of a hepa filter, the natural air current is greatly affected causing a high level of toxic gases within the cages.

Individually Ventilated Caging System

The modern concept of a caging system, the *Individually Ventilated Animal Caging System* (IVC) has proved to be the solution for almost all the issues faced in the open type caging system and filter top caging system. In this system, each cage is individually supplied with the required amount of clean air. The contaminated cage air is exhausted from each cage and discharged out of the animal room. The exhaust air is passed through necessary filters before entry to the exhaust ducts.

The *Individually Ventilated Animal Caging System* offers several advantages over the traditionally used open type caging system such as :

1) Improved safety of animals : The system offers much better safety to the animals as they are housed in an environment which is isolated from other cages in the room.

2) Hygienic conditions for the caretaker: The contaminated air is discharged directly out of the room and does not get mixed up with the room air. The room environment remains much fresher.

3) Conservation of environment : Exhaust air passed

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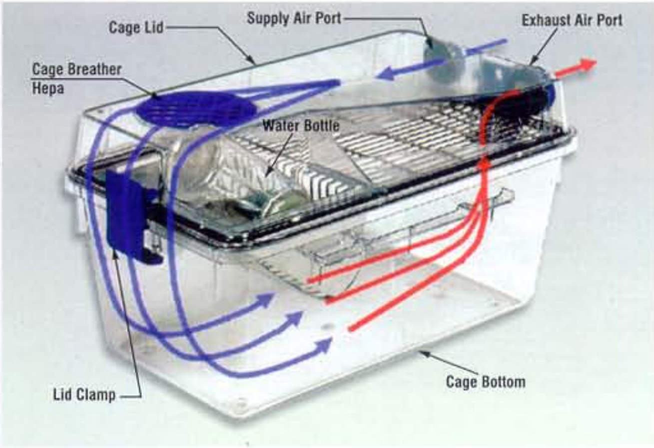

Figure 1 : IVC Cage detail

through micro / hepa filters eliminates the spread of biological contamination in the environment, outside the animal house.

4) Smaller area segmentation : Animals of different microbial status can be housed in the same room or even in the same rack as the cages are isolated from each other. This eliminates the requirement of different rooms for different experiments.

5) Control over cage environment : A specific physiological environment can be maintained very well through the facility to regulate both the supply and exhaust air quantity.

6) Hygienic conditions within the cage: Due to a smaller cage volume and forced air circulation system, it is possible to provide a high rate of air changes, as high as 40 to 60 air changes per hour in the cage, thus ensuring a much better environment within the cage.

7) Lesser frequency of cage changing : The higher ventilation rate keeps the animal bedding drier for a longer period. This reduces the cage changing frequency considerably.

8) Extra-ordinary energy saving : The total fresh air requirement is reduced to a large extent as the fresh air is supplied directly to the cages instead of the entire animal room. The total cage volume works out to be less than 10% of the room volume. In addition to a huge saving in energy cost, the temperature and humidity control becomes easier due to the reduced quantity of outside air.

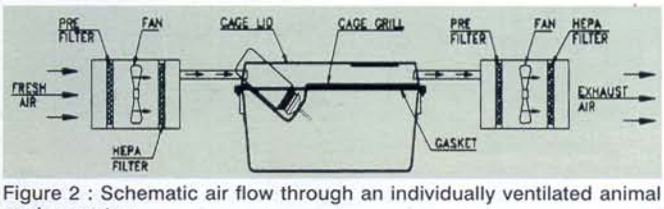

Figure 2 : Schematic air flow through an individually ventilated animal caging system.

9) Space saving : As the cages are provided with a forced air circulation system, very little space is required between two cages. This increases the storage capacity. The IV Animal Caging system stores a larger number of animals in a smaller space. Also the minimum requirement of space between two cages is reduced to a great extent due to the facility of forced ventilation compared to the traditional caging system.

10) Reduced maintenance : Considerable reduction in fresh air quantity requires much smaller filters resulting in reduced maintenance costs.

Frequently Asked Questions

1) IVC system is a power driven system, so what happens if the power supply fails?

It is true that the system should be fool proof. The following provisions will take care of animals in case of failure of the main power suply:

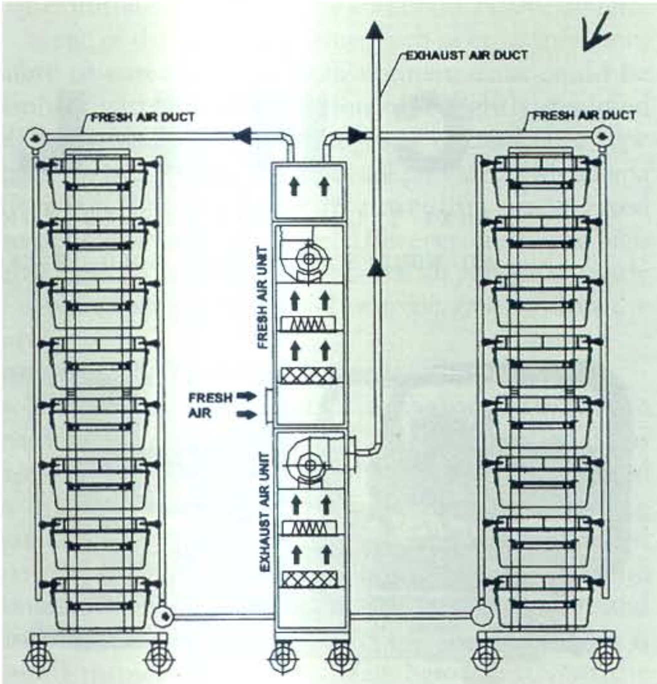

Figure 3 : Airflow through a compact battery of animal cages, each cage being individually ventilated.

a) The cage lid of IVC system is provided with an integral hepa filter element. A small amount of air circulation can take place through this filter, which is sufficient to take care of survival of the animal for 4 to 5 hours.

b) The total power requirement of ventilation units is very small (approx. 250 Watts). The unit can be equipped with a compact UPS which we commonly use for PCs. This will take care of the unit for atleast 2 to 3 hours.

c) In case of a large number of IVC installations,

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the animal house should be equipped with an alternate power source. In fact, the total power requirement of an animal house with an IVC system is much smaller compared to an animal house with a traditional caging system.

2) What happens to a hepa filter on the cage lid when the cages are autoclaved?

Cage lid hepa filter element is made out of a special material with protective scrim on both the sides. These filters have much better mechanical strength and can also withstand the washing and autoclave conditions (121°C, high humidity and steam pressure). However, these filters should be replaced regularly according to the manufacturer's recommendation.

3) What is the security if someone disturbs the setting of supply or exhaust air quantity?

The system is designed in such a way that parameters such as supply or exhaust air can be changed only with a special key. The settings of upper and lower limits are password protected. Generally, the senior caretaker sets the air quantities at the beginning of the experiment. The routine caretaker can hardly change any setting without the special key or password.

The system is generally provided with a dual alarm system. In case any of the important parameters such as SA quantity, exhaust air quantity, cage pressure, temperature or humidity goes beyond the set limit, a visual alarm light glows on the panel of IVC Ventilator. A system is also provided with a remote alarm port, which will provide an alarm even when the power supply of the system has failed or the fuse link is blown.

4) How does the system help in conservation of environment?

The contaminated exhaust air from cages is passed through a prefilter and hepa filters prior to discharge to the environment. This eliminates the spreading of biohazards to the surrounding areas. Also when we save energy, we save the environment as we consume a considerable amount of natural resources in producing electrical energy.

5) What is the cost comparison between a traditional caging system and an IV caging system?

Apparently, the cost of an IV caging system appears to be very high compared to the traditional caging system. However if we look at the total project cost, the cost of a project with IVC system generally works out to be much more economical as it offers considerable saving in total area requirement and in the first cost of an air conditioning plant.

Table 3 : Comparision of a traditional caging system and IVC system

Description	Animal House with Traditional caging system	Animal House with IVC system
Total Floor area of Animal House	1140 sq. mt.	712 sq. mt.
Animal housing capacity		
Mice	1379	2304
W. Rats	950	1440
SD Rats	1000	1080
BN and Lewis Rats	700	1080
Experimental mice	625	1280
Experimental rats	1350	2640
Future Provision - Rats	0	4320
Future Provision - Mice	0	1280
Total Animal Housing Capacity	**6004**	**15424**
Total air conditioning load	85 TR	30 TR
Air handling equipment (excluding standby equipment)	SA Fan-2Nos. 9500 CFM 1No. 9500 CFM	SA Fan-1No. 9500 CFM
	EA Fan-2Nos. 9500 CFM 1No. 7500 CFM	EA Fan-1No. 9500 CFM
	HR Wheel-2Nos. 1800 Dia	Not required
	Fan Motors-2Nos. 11.0 kW 2Nos. 9.3 kW	Fan Motors-1No. 9.3 kW Fan Motors-1No. 1.1 kW

Case Study

A renowned R&D center at Vadodara (Gujarat) established an animal facility with a conventional caging system. Within about 3 years the need arose for a new animal house as the existing capacity was falling short. As an alternate solution the company looked into the possibility of replacing the conventional caging system with an *Individually Ventilated Caging System*. Amazingly, the floor area requirement with the IV caging system was so small that the requirement of a new animal house became unnecessary. The new system also offered many other advantages such as:

- Animal housing capacity increased by 257%.
- Floor area requirement reduced by 38%.
- Total air conditioning load reduced by 65%.
- Air handling power reduced by 74%.
- 2x1800 dia Heat Recovery Wheels were spared, saving first cost, running cost & maintenance expense.

Table 3 shows a detailed comparison between the two systems.

Conclusion

In a country like India, *Individually Ventilated Caging Systems* should be the only choice over traditional caging systems as we are greatly concerned with all four of its basic advantages i.e. better environment for animals, conservation of energy, conservation of the environment and reduction in the total project cost. ❖