VARIABLE PATTERN CONTAMINATION CONTROL UNDER POSITIVE PRESSURE

Hardy M. Philippi
Chalk River Laboratories
Atomic Energy of Canada Limited
Chalk River, Ontario, Canada K0J 1P0

Abstract

Airborne contamination control in nuclear and biological laboratories is traditionally achieved by directing the space ventilation air at subatmospheric pressures in one fixed flow pattern. However, biological and nuclear contamination flow control in the new Biological Research Facility, to be commissioned at the Chalk River Laboratories in 1996, will have the flexibility to institute a number of contamination control patterns, all achieved at positive (above atmospheric) pressures. This flexibility feature, made possible by means of a digitally controlled ventilation system, changes the facility ventilation system from being a relatively rigid building service operated by plant personnel into a flexible building service which can be operated by the facility research personnel. This paper focuses on and describes the application of these unique contamination control features in the design of the new Biological Research Facility.

I. Introduction

Airborne contamination control in nuclear and biological laboratories is traditionally achieved by directing the space ventilation air at subatmospheric pressures in one fixed flow pattern. However, in the new Biological Research Facility (BRF) to be commissioned at the Chalk River Laboratories in 1996, the ventilation system will have the flexibility to effect a number of contamination control patterns at positive (above atmospheric) pressures. This pattern flexibility feature, made possible by means of a digitally controlled ventilation system, provides the researcher with the ability to design contamination control patterns which serve the unique requirements of each research program and to accommodate abnormal ventilation system conditions. The ventilation system is therefore no longer a relatively rigid building service operated by plant personnel, but it can become the direct responsibility of the research personnel who are intimately aware of animal welfare and the research program requirements. The requirement to pressurize the facility arises from the fact that the animal housing rooms, laboratories which may temporarily house animals and the animal care support rooms must be pressurized with High-Efficiency Particulate Air (HEPA) filter ventilation air in order to minimize the intrusion of air-borne contamination (viruses and bacteria) from the outside.

This paper focuses on and describes this unique contamination control approach as it is applied in the BRF. (Ref. Figure 1 Main Floor Plan & Figure 2 Upper Floor Plan). The BRF classification, hazards, special requirements and a brief ventilation system description are given to provide a facility overview and an appreciation of its contamination control issues.

II. Facility Usage, Hazards, Classification & Requirements

The new BRF will be used to conduct animal-based biological research work on rodents using carcinogens, radiation and radioisotopes. The research is primarily to study the carcinogenic effects of ionizing radiation separately and in combination with other materials and the facility is intended to support these studies at the molecular, cellular and whole-animal levels.

Hazardous materials used in the research laboratories are limited to small quantities of:

- carcinogenic tumor initiators (DMBA and MNNG) and promoters (TPA and Mezerein);
- Radioisotopes (Tritiated water, tritiated organic compounds, C-14 amino acid or other C-14 compounds); and
- uranium oxide (dust).

The external beam radiation facilities utilizes Co-60 and Sr-90. [1]

The facility is classified as CRL Category 2, that is, one where the potential for a significant hazard is limited to the facility and its operators. [2]

The BRF specification included the following requirements to provide

- animal housing and care to meet and exceed current Canadian Council on Animal Care standards [3];
- a research environment consistent with quality-assured research programs;
- effective, predictable and flexible contamination control means under both normal * and abnormal ** operating conditions;
- a safe, licensable laboratory; and
- ALARA working conditions for the facility operating and research staff.

III. Ventilation System Description

Ventilation System:

The supply side of the ventilation system consists of two parallel roof-mounted draw-through air-handling and air-conditioning units, each rated at 50% of the total building ventilation air supply rate. Each unit has means to prefilter, heat, cool/dehumidify, reheat, supply and final filter the building fresh air supply to meet the building space air change and environmental conditioning requirements. Supply air terminal reheat is provided to meet the specific temperature requirements of each room and laboratory. The ventilation exhaust side consists of the following six main exhaust systems:

E-1/2/3 General Building Exhaust ***
E-4/5/6 Fumehood and BSC Exhaust ***
E-7/8/9 Carcinogen Area Exhaust ***
E-10 Janitor and Washroom Exhaust,
E-12/13 Scavenger and Solvent Storage Exhaust and
E-14/15 Cage Washer Exhaust

---

* Normal operating conditions are day-to-day operations when all electrical power demands are met from the local electrical power utility, all ventilation system equipment is functioning or available and all ventilation and contamination control requirements are achieved.

** Abnormal operating conditions are when the facility is on limited standby diesel-generated electrical power or when vital ventilation equipment is not available because of failure or maintenance outage.

*** Any two fans can achieve full system exhaust rate.

Due to severe budget limitations this project could not support the provision of 100% standby boilers, diesel generated electrical power and ventilation system redundancy. Alternative design features, described in Section VII, were therefore provided to ensure continuous normal operating condition ventilation rates to all rooms housing animals under both maintenance outage and power-failure abnormal condition scenarios.

Ventilation System Control:

Ventilation system supply and exhaust flow control is by Direct Digital Control (DDC). The DDC system to operator interface is by means of a central computer unit (CCU), which is basically a personal computer complete with a keyboard , screen and various in/output devices. The CCU directs and monitors a number of remote processing units, which in turn regulate the terminal equipment controllers.

The system is programmed to automatically regulate the ventilation system variable volume ventilation (VAV) boxes, equipment start/stop and damper or valve open/shut functions to one specific contamination control pattern until it is manually or automatically told to change to another pattern. Each pattern is a memorized number of ventilation system VAV box-flow-rate set points together with preset start-stop functions for several lesser ventilation systems. Pattern changes are initiated automatically when an abnormal condition is detected or manually to suit a different research program requirement. The system continually monitors specific system conditions and will automatically change to a suitable abnormal conditions pattern.

The facility operator can automatically or manually monitor and record facility environmental conditions, select preprogrammed operational scenarios or manually adjust individual system parameters and receive system annunciation and failure alarms. The remote processing units will stand alone and provide local system control even though they are disconnected from the CCU.

IV. Ventilation System Balancing

Balancing the BRF ventilation system supply and exhaust flow rates is vital to understanding, developing and documenting the various ventilation air flow patterns required to meet the normal and abnormal facility operations requirements. A basic spread sheet was prepared to account for and balance the supply, exhaust and in/out leakage for each of 68 spaces in the facility. Spaces varied in size from a 37 m-(120') long irradiation room to a 1 m-(3.3') deep janitor's closet under normal conditions. This basic normal operations ventilation system balance pattern is the starting point for the development alternative normal and abnormal operations patterns. All patterns have to be checked against the capabilities of the fan systems and the 110 space supply and exhaust VAV boxes. It should be noted that the accuracy and control range of VAV boxes is ± 24 L/s (50 cfm) of their set point down to about 20% of their rated flow. A number of VAV boxes serving nonanimal related spaces may be shut off under abnormal conditions. Figure 3 is a typical balancing spread sheet for rooms Y144, Y146 and Y148. Note that all the exhaust, transfer, out-leakage, supply and in-leakage rates are rigorously accounted for. It is through this form of accounting that any room rate changes being considered for a new pattern can be assessed for their impact on the whole building ventilation system capability.

V. Facility Contamination Control Features:

A broad range of contamination control features that affect all aspects of facility operations, covering all contamination routes into, within and out of the facility were incorporated into the BRF design. All rooms are color-coded denoting the space usage, contamination potential and appropriate material and personnel traffic limitations. Special consideration was taken in the design of ventilation, mechanical and electrical services for each color-coded area so that their peculiar requirements were met.

The main features are:

Facility Personnel and Material Traffic Contamination Control:

The BRF is connected to an adjacent Biology Laboratory Building by a second floor bridge. Entry is electronically controlled and research personnel entering the facility shower and change into appropriate clothing on the second floor level before proceeding to the main floor.

Shipping and receiving entrances, at the main floor level, are equipped with fumigation, sterilization and storage facilities to control the entry and exit of contaminated materials.

Facility Contamination Arising from Maintenance Operations:

The facility building upper level plan (Figure 2) shows that an area almost as large as the entire building plan is provided for mechanical and electrical services. A considerable effort has gone into separating service equipment and piping from the animal and laboratory spaces. The location of ventilation equipment, ducting, dampers, piping, valves, power supplies, electrical panels, controls and instrumentation outside of the animal and laboratory spaces minimizes the probability that maintenance personnel will have to enter them.

Airborne Contamination Entry from Outside:

The number of window and door penetrations in the facility exterior building wall have been kept to a minimum and, by keeping the building at above atmospheric pressure with an over-supply of HEPA-filtered and temperature/humidity-conditioned air, out-leakage at the building perimeter minimizes the entry of airborne contaminants from outside the building.

Airborne Contamination Movement Within the Building:

The uncontrolled movement of facility ventilation air is minimized by placing great emphasis on sealing all wall, ceiling and floor penetrations. The controlled movement of facility ventilation air is effected by regulating the relative rates of room supply and exhaust. This regulation of room ventilation air supply and exhaust rates is used to produce directional air flow patterns and air change rates customized for the specific research program requirements. For example, in Figure 4 the animal holding rooms, Y144 and Y148, are over-supplied to leak ventilation air into the adjacent ante room, Y146, which in turn leaks it to an adjacent corridor.

Airborne Contamination Movement When a Door Between Adjacent Rooms is Opened:

There is a relatively small contingent of personnel (3 to 5 people) in charge of the facility. Entry into the facility by other research, operating and maintenance personnel is very restricted. Facility operating personnel are trained to work to formal procedures and are aware of the special requirements of the animal based research facility. Room-to-room traffic is kept to a minimum: thus doors between adjacent spaces are closed most of the time and only opened for very short periods throughout a typical work day for very specific purposes. It is recognized that the rate of flow through an open door is too small to prevent upstream contamination movement. However, adjacent spaces such as the ante rooms, serve as air-locks that minimize/restrict the spread/flow of contamination to areas that are beyond the immediate attention of the trained personnel entering or leaving the area.

Work Station Airborne Contamination Control:

Work stations such as Class II B2 Bio-safety cabinets (BSC) and fume hoods, located inside the above atmospheric pressure rooms and laboratories, serve to control the spread of contamination from the stations by maintaining inflow velocities consistent with proper cabinet and fume-hood operation practices.

Animal Cage Airborne Contamination Control:

Recent developments in small animal cages rack designs, Figure 5, have included a means of connecting each rack of cages directly to the building HVAC system, thereby isolating each animal cage from the ones adjacent to it and providing each cage with a known ventilation supply and exhaust rate. As this development becomes the norm for up-to-date animal care, this facility will be able to accommodate the change from room supply and exhaust ventilation to a combination of room and direct cage rack ventilation. An additional complexity is introduced here in that the number of racks in each animal holding room is a variable that must be accommodated by the room ventilation supply and exhaust control system. The BRF animal housing room and laboratory ventilation systems have the ability to divert room ventilation air to and from one to six cage racks in each housing room.

VI. Normal Operations Contamination Control Pattern Variations

Typical Pattern With Direct Room Ventilation

The Figure 4 Normal Operations #1a Pattern Diagrammatic Flow Sheet shows Rooms Y144, Y146 and Y148 with direct room ventilation. The excess supply air is shown as out-leakage and is added to the exhaust total to create a supply and exhaust balance in the room. The out-leakage of course becomes part of the supply balance in the adjacent Y146 room. Any number of Normal Operations ventilation patterns can be devised to suit current research programs. For example, Room Y144 could be balanced to leak inwards from Room Y146.

Typical Pattern with Direct Cage Ventilation

Figure 6 shows the Normal Operations #1b Pattern Diagrammatic Flow Sheet for Animal Housing Room Y144 when it is equipped with six directly ventilated cage racks rated at 28 L/s (60 cfm) supply and exhaust. The total animal housing room rack exhaust and supply rates of 170 L/s (360 cfm) are diverted from the direct room supply and exhaust ventilation rates. The room ventilation air change rate is however not allowed to drop below a prescribed value. A number of contamination control patterns with direct cage ventilation for from one to six cage racks to suit current research programs will be required for each room equipped with ventilated cage rack supply and exhaust services.

VII. Abnormal Operations Contamination Control Pattern Variations

The ability to provide flexible ventilation/contamination control patterns provides a method of dealing with abnormal power and equipment outage conditions. Figure 7 shows the Abnormal Conditions Pattern #2 diagrammatic arrangement for Animal Housing Rooms, Y144. Y146 and Y148, where the fume-hood exhaust rate in Room Y146 is reduced to conserve supply air for the animal related spaces. The DDC-controlled ventilation system is thereby able to provide normal contamination control patterns in animal-related rooms, and rooms that can tolerate ventilation changes are either shut down or their rates are significantly reduced during the abnormal condition.

VIII. Conclusion

Variable contamination control pattern capability provides facility operations flexibility that meets current and future animal welfare and research program environmental requirements. It takes facility ventilation systems from being a relatively rigid building service operated by plant operating personnel and gives facility research personnel the responsibility for and means to provide quality-assured animal, personnel and program environments.

IX. References

1	NSN-ESRSD-140	AECL, CRL Environmental Safety & Regulatory Services, Safety Analysis Report of the Biological Research Facility (BRF)
2	SRC-R-1	AECL Safety Review Committee Requirements for Review and Approval of New Facilities
3	CCAC	Canadian Council on Animal Care Guideline

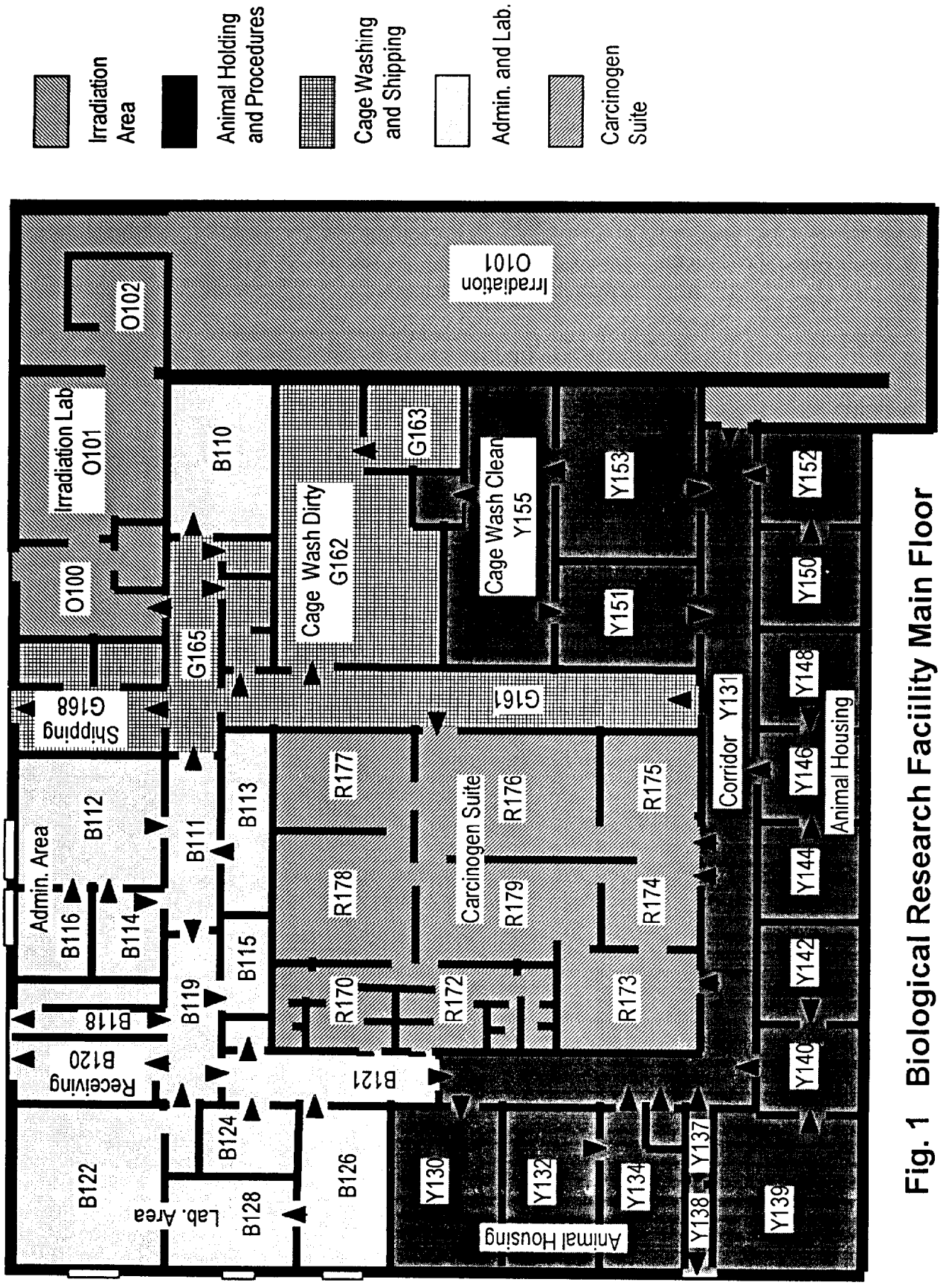

Fig. 1 Biological Research Facility Main Floor

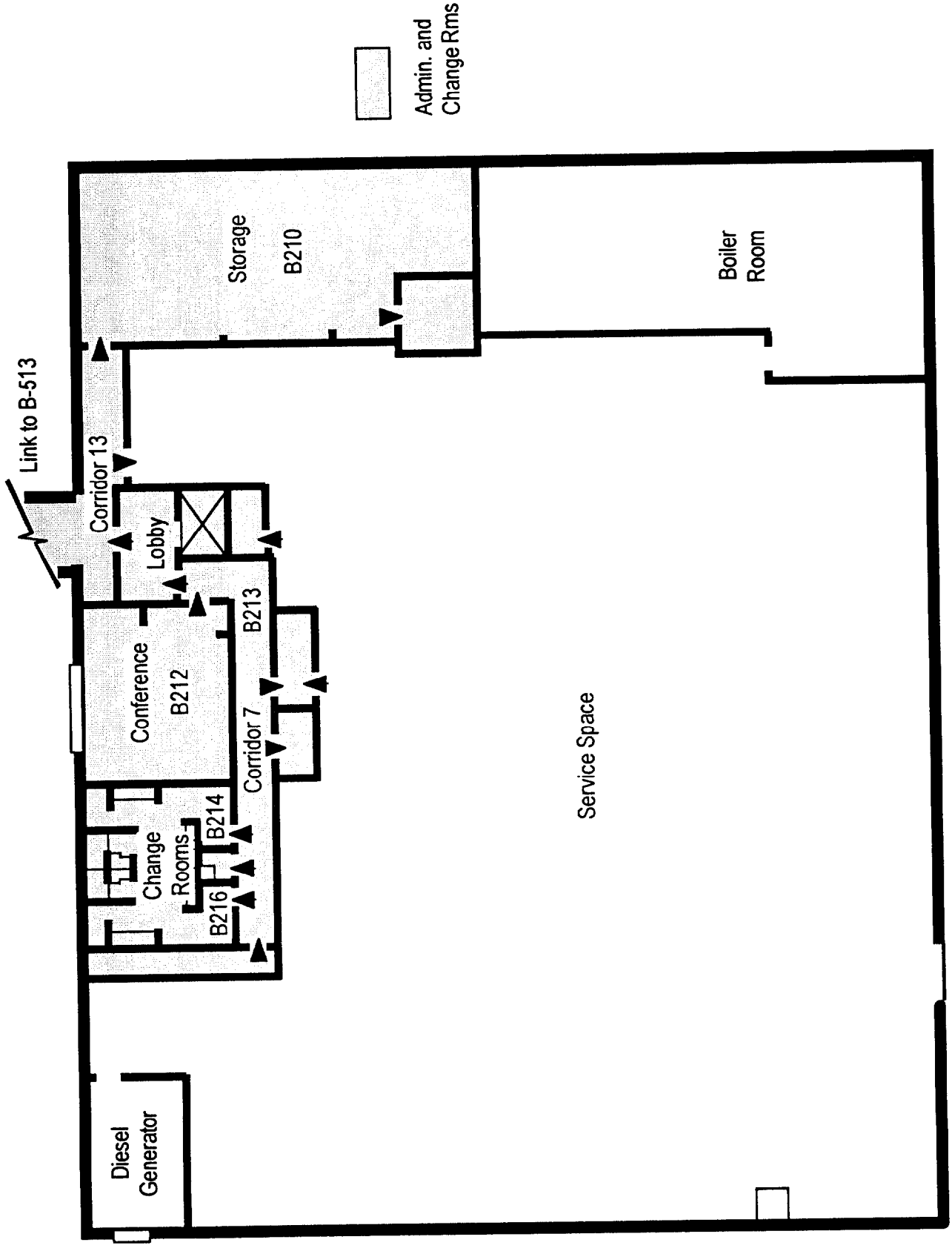

Fig. 2 Biological Research Facility Upper Floor

Rm Y144 Housing AB		Exhaust Fan System (litres / sec.)									OUTFLOW (litres / sec.)			INFLOW (litres / sec.)			
		VAV #	E-123	E-456	E-789	E-10	E-1213	E-14	E-15	Transf	Exh.	Transf	Exfilt.	VAV #	Supply	Transf	Infilt.
Length (m)	Room	Y144EB1	198											Y144SB1	245		
4.0	Doors																
Width (m)	146												47				
4.0	sealed145																
Height (m)	Transfer																
2.6	Rack	Y144EB2	0											Y144SB2	0		
Vol. (m3)	Fume:																
41.6	Fume Hood																
Room	BSc																
Chg./Hr	Canopy																
21.2	Room Totals		198	0	0	0	0	0	0	0	198	0	47		245	0	0

Rm Y146 AnteRoom AB		Exhaust Fan System (litres / sec.)									OUTFLOW (litres / sec.)			INFLOW (litres / sec.)			
		VAV #	E-123	E-456	E-789	E-10	E-1213	E-14	E-15	Transf	Exh.	Transf	Exfilt.	VAV #	Supply	Transf	Infilt.
Length (m)	Room													Y146SB1	496		
4.0	Doors																
Width (m)	147												47				
3.6	146 148																94
Height (m)	Transfer																
2.6	Rack	Y146EB2	0											Y146SB2	0		
Vol. (m3)	Fume:																
37.4	Fume Hood	Y146EB1		543													
Room	BSc																
Chg./Hr	Canopy																
56.7	Room Totals		0	543	0	0	0	0	0	0	543	0	47		496	0	94

Rm Y148 Housing AD		Exhaust Fan System (litres / sec.)									OUTFLOW (litres / sec.)			INFLOW (litres / sec.)			
		VAV #	E-123	E-456	E-789	E-10	E-1213	E-14	E-15	Transf	Exh.	Transf	Exfilt.	VAV #	Supply	Transf	Infilt.
Length (m)	Room	Y148EB1	198											Y148SB1	245		
4.0	Doors																
Width (m)	148												47				
4.0	sealed149																
Height (m)	Transfer																
2.6	Rack	Y148EB2	0											Y148SB2	0		
Vol. (m3)	Fume:																
41.6	Fume Hood																
Room	BSc																
Chg./Hr	Canopy																
21.2	Room Totals		198	0	0	0	0	0	0	0	198	0	47		245	0	0

FIG. 3 BRF - Normal Contamination Control Pattern #1a (No Ventilated Racks)

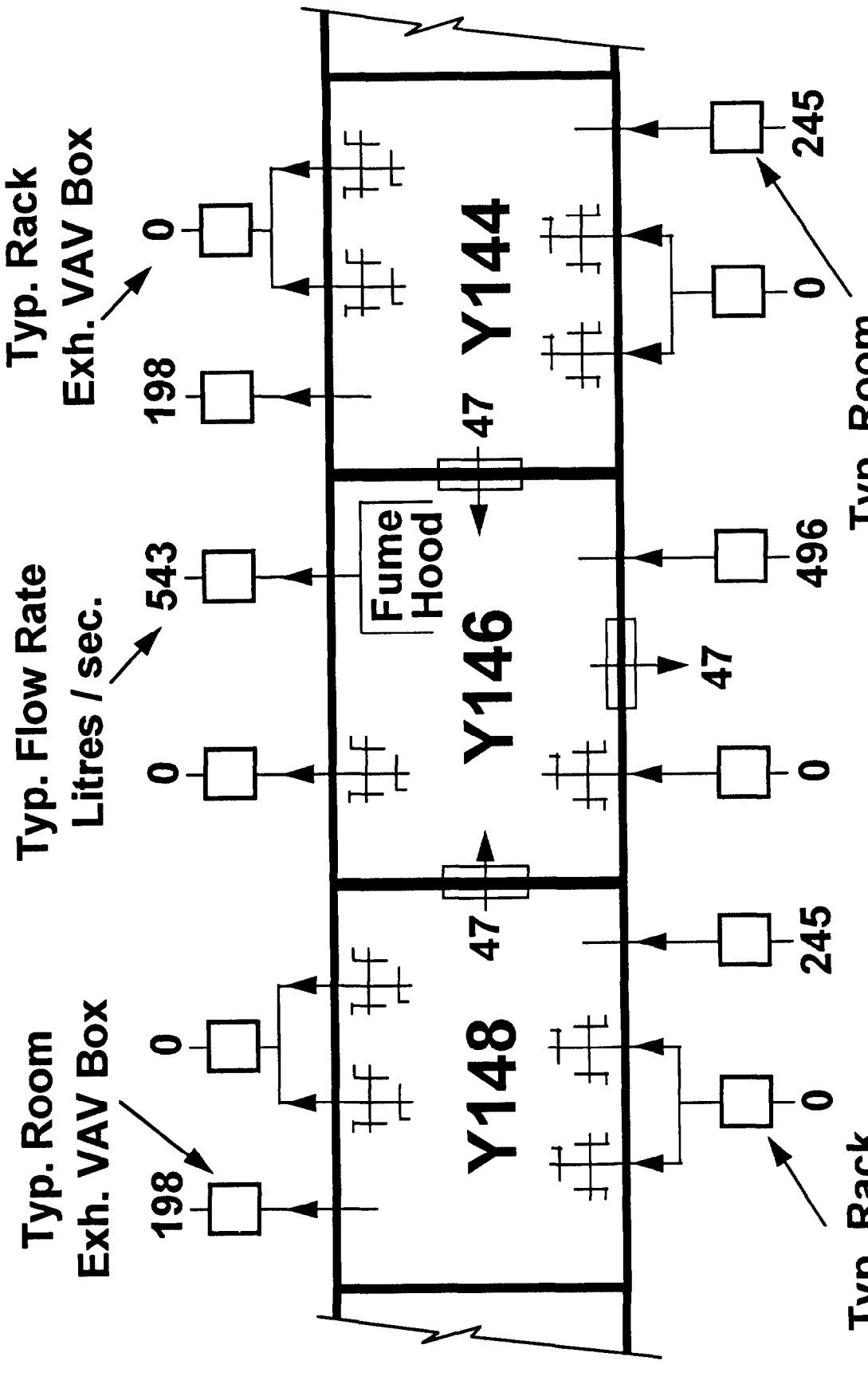

FIG. 4 Bioological Research FacilityNormal Conditions
Pattern #1a Rooms. Y144, Y146 and Y148 Flow Sheet Diag.

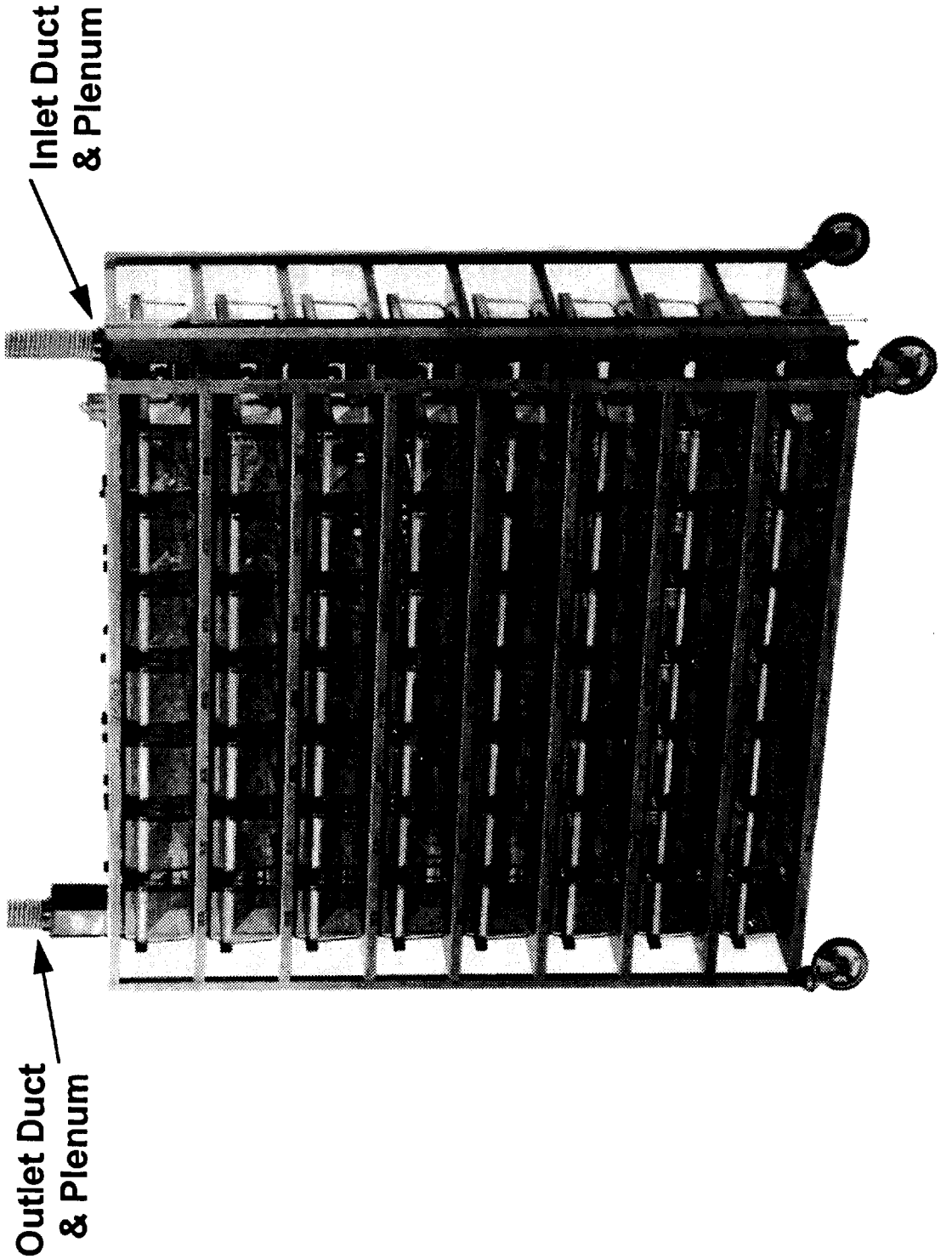

FIG. 5 Biological Research Facility Directly Ventilated Animal Cage Rack

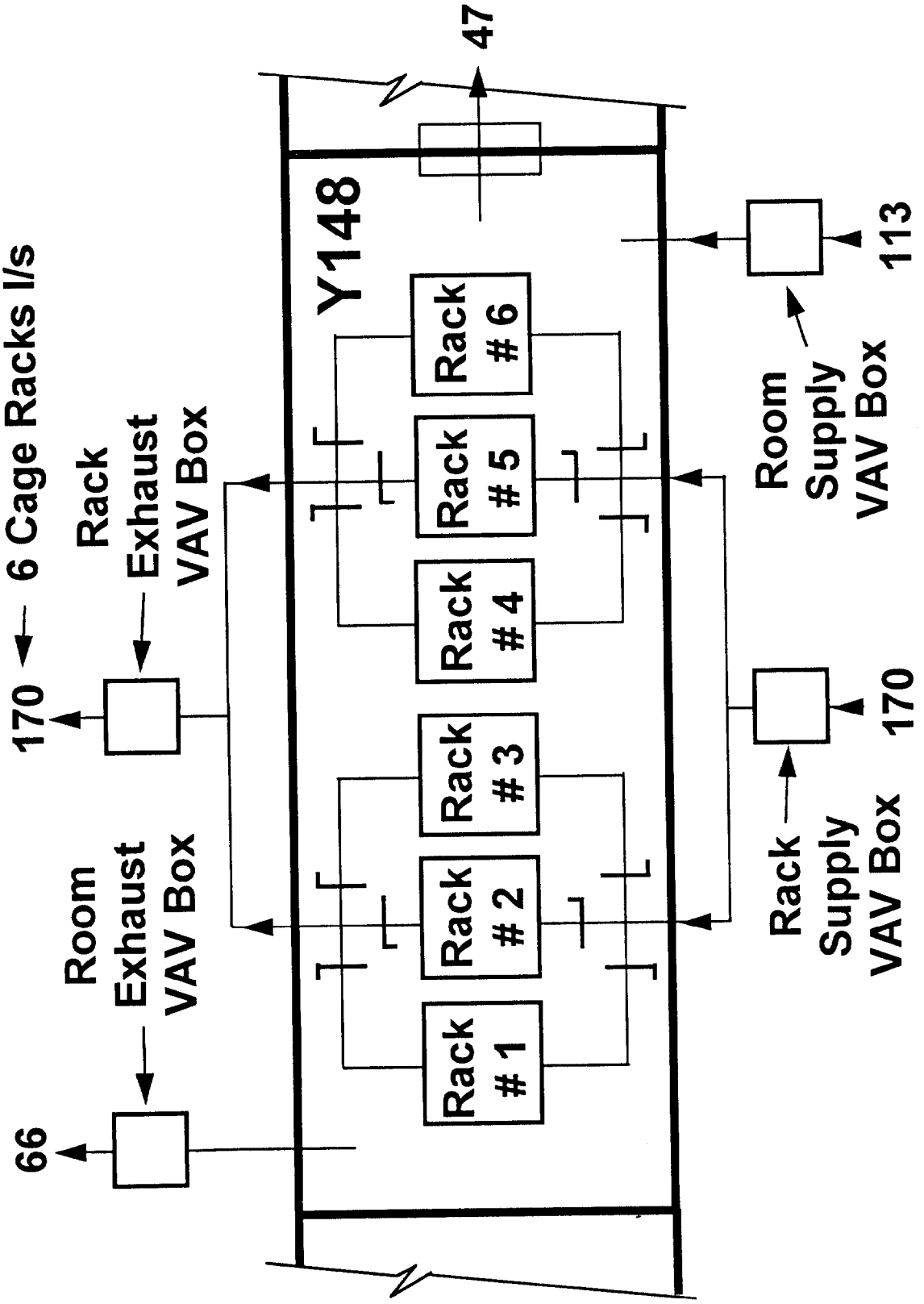

FIG. 6 Biological Research Facility Normal Conditions Pattern #1B Room. Y144 Flow Sheet Diag.

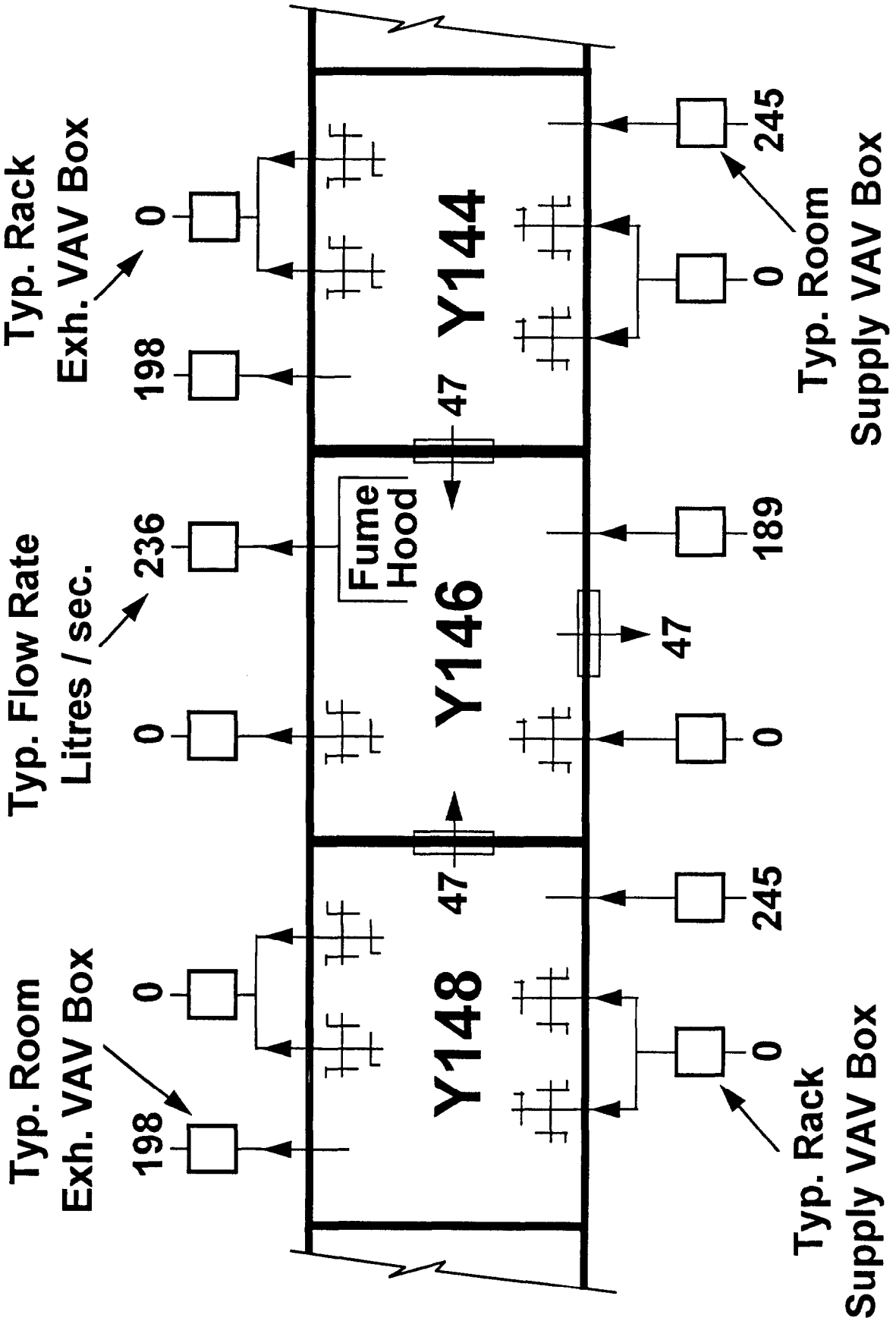

FIG. 7 Biological Research Facility Abnormal Conditions Pattern #2 Room. Y144 Flow Sheet Diag.