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ASHRAE Annual Conference
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Engineering | Architecture | Design-Build | Surveying | GeoSpatial Solutions MERRICK & COMPANY

Learning Objectives

- Objective 1 - Describe the concept of pressure reversal, also known as air flow reversal in containment laboratories and define where the pressure reversals are not allowed, and where they are permitted.
- Objective 2 - Describe the National Institutes of Health and Centers for Disease Control oversight of BSL-3 facilities.
- Objective 3 - Explain differences between biocontainment facility commissioning and annual performance verification and understand the distinction of ANSI Z9.14 and "Select Agent" rules as they relate to performance verification.
- Objective 4 - Understand what options are available to simplify the design of biocontainment facility HVAC to reduce costs.

Acknowledgments

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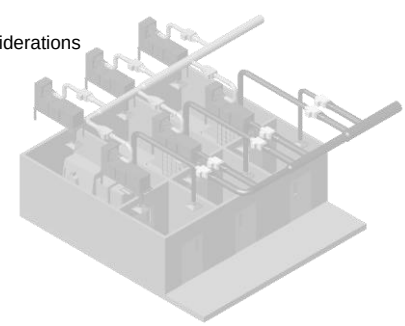
- Scott Rusk – KSU Biosecurity Research Institute
- Jack Keene – Global Biohazard Technologies, Inc.

Agenda

- Definitions
- Guidelines
- Design Considerations
- Examples
- Conclusions



Definitions

- BSL – BioSafety Laboratory
- BSL-1 - The basic level of protection and is appropriate for agents that are not known to cause disease in normal, healthy humans.
- BSL-2 - Appropriate for handling moderate-risk agents that cause human disease of varying severity by ingestion or through percutaneous or mucous membrane exposure.
- BSL-3 - Agents with a known potential for aerosol transmission, for agents that may cause serious and potentially lethal infections and that are indigenous or exotic in origin.
- BSL-4 - Exotic agents that pose a high individual risk of life-threatening disease by infectious aerosols and for which no treatment is available.
- BMBL - Biosafety in Microbiological and Biomedical Laboratories
- CDC – Centers for Disease Control and Prevention
- NIH – National Institutes of Health

CDC-BMBL 5th Edition

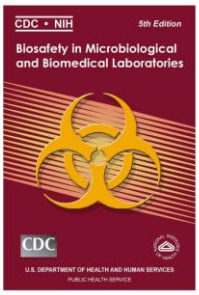
- 4th Edition Statement

~~"Consideration should be given to installing an HVAC control system to prevent sustained positive pressurization of the laboratory"~~

Removed in 5th Edition

NOW in BMBL 5th ed

"The laboratory shall be designed such that under failure conditions the airflow will not be reversed"



NIH Guidelines

- NIH Design Guide (2008)
  - Section 7-3 BAS Application Requirements: 7-3-00 E.1 Page 7-23

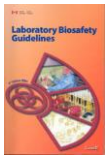
Pressure control shall maintain space pressures between -12.5 Pa and -25 Pa. There shall never be a condition in which the control system goes outside this range for more than two minutes ~~or goes positive for more than 30 seconds.~~ and directional airflow must be sustained by drawing air into the laboratory from "clean" areas toward 'potentially contaminated areas'. The laboratory shall be designed such that under failure conditions the airflow will not be reversed

(Revised 8/27/09)

Other Guidelines Verbiage

Canada: Laboratory Biosafety Guidelines (3rd Edition, 2004)

"Control systems to be tested for fail-safe operation by failure of system components, (i.e., exhaust fan failure, supply fan failure, power failure [where possible], Class II B2 BSC exhaust failure). This is to include audible/visual alarm testing. Acceptance criteria: inward directional airflow. The sustained reversal of airflow across containment barrier is to be prevented…."
Reaffirmed in 2013 edition of guidelines



WHO Biosafety Manual - (3rd Edition, 2004)

"A heating,ventilation and air-conditioning (HVAC) control system may be installed to prevent sustained positive pressurization of the laboratory."

What CDC Officials are now saying

a. Mechanical failure of exhaust fan or fan component(s):

- If redundant fans are present, the ability to transition to the alternate fan without reversal of air flow from potentially contaminated laboratory space into "clean" areas surrounding the laboratory must be verified.
- If no redundancy is present in the laboratory HVAC system, the capacity to transition from sustained inward air flow into the laboratory to a "static" condition, i.e., no air flow out of the laboratory must be verified.

b. Simultaneous power failure supporting supply and exhaust fan components:

- If emergency power supply is available for the laboratory HVAC system, the ability to transition from "normal" power to the backup system without a reversal of air flow from the laboratory should be verified.
- If no backup power supply is available, the ability of the HVAC system to transition to a "static" condition, i.e., no outward air flow, should be verified.

c. Return from power failure to "normal" operating conditions:

- If emergency power supply is available, it should be verified that the ability exists to transition from backup power to normal power without a reversal of air flow from the laboratory.
- If no backup power supply is available, the ability of the HVAC system to return to normal operating conditions, without a reversal of air flow from laboratory spaces to clean areas surrounding the laboratory should be verified.

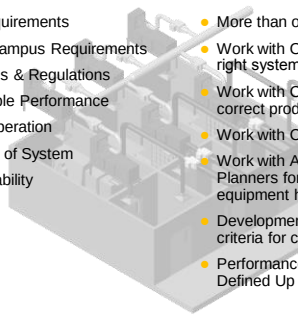
What CDC Officials are now saying

- The documentation provided must demonstrate that under exhaust fan or normal power failure conditions, or during normal power start-up, there is no reversal of air which originates within the BSL-3/ABSL-3 laboratory or vivarium room that travels all of the way outside the containment boundary. A facility may be considered to pass the HVAC verification tests as long as laboratory air does not exit the containment barrier of the facility. The BSL-3 anteroom is considered to be within the containment envelope.
- A positive pressure excursion is not necessarily an airflow reversal; if a brief, weak positive pressure excursion is noted, a repeat test may be performed with airflow observation using an airflow indicator such as a smokestick, or dry ice in a container of water, at the base of the closed laboratory door to confirm whether airflow reversal is occurring.

Design Issues

Factors to consider during design phase

- User Requirements
- Facility/Campus Requirements
- Guidelines & Regulations
- Repeatable Performance
- Stable Operation
- Flexibility of System
- Maintainability

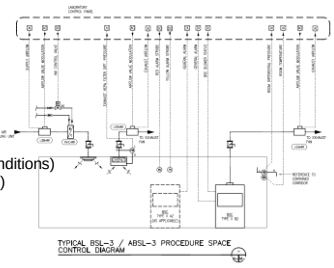


- More than one solution
- Work with Owner/Users to select right system for SOP's
- Work with Controls Vendors for correct product application
- Work with Cx Agent
- Work with Architects and Lab Planners for lab tightness, equipment heat loads, etc.
- Development of room tightness criteria for contractors
- Performance Criteria Must be Defined Up Front

Design Issues

There are three general types of Airflow Control

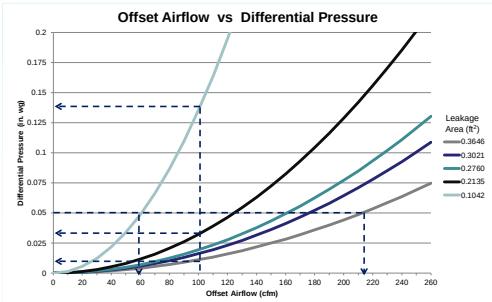
- Offset Airflow Control
- Offset Airflow with dP reset
- Differential Pressure Control



No Reversal (under failure conditions)

- Interlocks (system or device)
- Fast acting controls
- Emergency power back-up

Design Issues



- 2015 ASHRAE Handbook HVAC Applications (Ch. 53)

$$Q = 2610 A \sqrt{\Delta P}$$

Design Issues

Engineered Leaks

Backdraft Dampers

Adjustable Openings

Filtered Bypass

Adjustable Door Seals

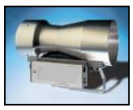
Design Issues

- Room tightness for BSL3 labs should be based on CFM loss/area for all unplanned leaks- each lab is different
- Walls and ceilings should be designed to resist lateral, vertical bi-directional for maximum pressures caused by fan failures; Ideally this should be at least greater than 1000Pa (4"wg) or the maximum anticipated pressures under fan failures

Design Issues

- **Single Blade Damper**
  - Low Capital Costs
  - Simple
  - Can maintain the valve assembly without removing from the ductwork
  - Can be Fast Acting
  - Non linear
  - Must maintain min. velocities for airflow measurement.

- **Venturi Valve**
  - Large operating range
  - Pressure Independent
  - Fast Acting
  - Spring can become damaged on over pressurization
  - Must remove valve from ductwork to maintain valve assembly
  - Capital Costs are high
  - Indirect flow feedback



- **Bladder Valve**
  - Simple & Durable
  - Can maintain the valve assembly without removing from the ductwork
  - Fast Acting
  - Capital Costs are high
  - Must maintain min. velocities for airflow measurement.
  - Requires Pneumatic Air

Design Issues

LAB SPACE:
GENERAL: EACH LABORATORY SHALL BE PROVIDED WITH A LAB CONTROLLER CAPABLE OF SPACE TEMPERATURE CONTROL AND MAINTAINING A CONSTANT AIRFLOW OFFSET BETWEEN SUPPLY AND TOTAL EXHAUST AIR AND NO REVERSAL OF AIRFLOW UNDER FAILURE CONDITIONS.

HOT WATER REHEAT COIL:
CONTROL: THE REHEAT HOT WATER CONTROL VALVE SHALL BE MODULATED TO MAINTAIN SPACE TEMPERATURE SETPOINT.

ROOM START-UP:
ON A COMMAND FROM THE BAS, THE LAB CONTROLLER SHALL MODULATE THE GENERAL EXHAUST VALVE TO THE OCCUPIED MODE AIRFLOW SETPOINT (ADJUSTABLE). THE SUPPLY VALVE SHALL MODULATE TO MAINTAIN THE SETPOINT OFFSET AIRFLOW DIFFERENTIAL FROM THE TOTAL ROOM EXHAUST

OCCUPIED MODE:
DURING OCCUPIED MODE, THE GENERAL EXHAUST VALVE SHALL MODULATE TO MAINTAIN A TOTAL ROOM EXHAUST (GENERAL + BIOSAFETY CABINET) AS NECESSARY TO MAINTAIN THE OCCUPIED MODE AIR CHANGE RATE (REFER TO MAXIMUM AIRFLOW LISTED IN THE AIRFLOW CONTROL VALVE SCHEDULES).

NIGHT SETBACK MODE:
NIGHT SETBACK MODE SHALL BE INITIATED BASED ON A 7-DAYWEEK TIME SCHEDULE. DURING NIGHT SETBACK MODE, THE GENERAL EXHAUST VALVE SHALL MODULATE TO MAINTAIN A TOTAL ROOM EXHAUST (GENERAL + BIOSAFETY CABINET) AS NECESSARY TO MAINTAIN THE NIGHT SETBACK MODE AIR CHANGE RATE (REFER TO MINIMUM AIRFLOW LISTED IN THE AIRFLOW CONTROL VALVE SCHEDULES). A PUSH BUTTON SWITCH SHALL BE PROVIDED IN EACH LAB TO OVERRIDE NIGHT SETBACK MODE AND INITIATE OCCUPIED MODE FOR 2 HOURS (ADJUSTABLE).

ROOM SHUTDOWN:
ON A COMMAND FROM THE BAS, THE LAB CONTROLLER SHALL MODULATE THE GENERAL EXHAUST AND SUPPLY VALVES CLOSED. CLOSING OF THE VALVES SHALL BE SEQUENCED TO ENSURE THAT THE LAB IS NOT POSITIVELY PRESSURIZED DURING SHUTDOWN.

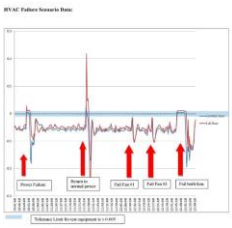
TYPE II B2 BIOSAFETY CABINET OPERATION (WHERE APPLICABLE):
WHEN THE BIOSAFETY CABINET BLOWER IS TURNED ON AT THE CABINET, A CONFIRMATION SIGNAL SHALL BE SENT TO THE INTERLOCKS TO THE EXHAUST FANS AND MODULATE BIOSAFETY EXHAUST VALVES TO THE OPEN POSITION. THE GENERAL EXHAUST VALVES SHALL MODULATE TO MAINTAIN THE TOTAL ROOM EXHAUST (GENERAL + BIOSAFETY CABINET) SETPOINT. LABORATORY SHALL BE INTERLOCKED TO PREVENT THE CONTROLS FROM ENTERING INTO NIGHT SETBACK MODE WHILE THE BIOSAFETY CABINET IS OPERATING.

Sequence of Operations

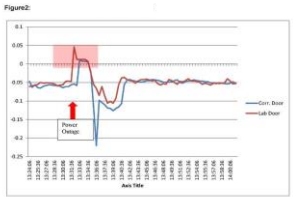
- Start up
- Shut down
- Interlocks
- Normal operations
  - Occupied
  - Unoccupied
  - Decon mode
- Failure modes
- Equipment Loading
- Maintenance Mode
- Pass/Fail Criteria

Case Study 1

Uncontrollable Variables



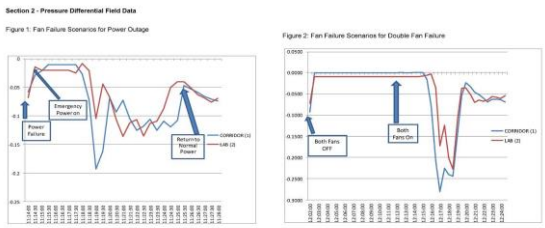
Airflow Test #1- Fail
June 28, 2011



- Modifications Included:
  - Loop Tuning
  - Changed to high speed actuator

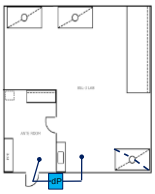
Case Study 1

Successful Outcomes



Airflow Test #2 - Pass
July 19, 2011

Case Study 2

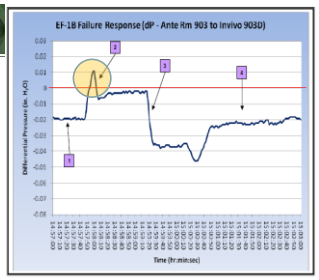


HVAC configuration:

- Bladder valves on supply and exhaust. Active pressure control of supply valve.

Conclusions

- Many labs experience positive pressure "blips" during fan failures
- Speed of response of BAS is critical to minimize/eliminate positive pressure spikes
- Elimination of positive pressure spikes during exhaust fan failures is difficult to achieve

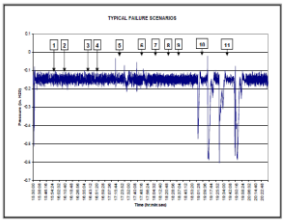


OBSERVATIONS/RESULTS:

1. EF-1B was operating as lead and EF-1A was the lag fan. Failed EF-1B.
2. Invivo Rm 903D went positive for approx. 8 seconds and dropped down to negative. During this time, the RTU isolation dampers closed and the unit shut down to prevent positive pressurization.
3. Stand-by / lag EF-1A started up and brought space back to a negative condition.
4. RTU restarted and EF-1A now lead – normal steady state conditions restored automatically

Conclusions

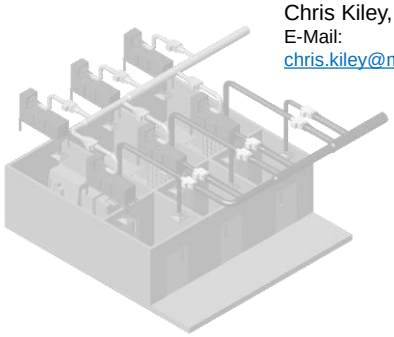
- Pressure excursions do not necessarily mean a airflow reversal
- A well described design and a qualified commissioning process can maintain negative pressures during fan failures
- To achieve this,
  - fast BAS communications,
  - hard-wired controlled shutdowns to dampers/ supply fans,
  - fast reacting devices and
  - fine-tuning of software programs



OBSERVATIONS:

Note	Time	Test	Result
1	15:55:00	Failed EF-2TA	No Impact
	16:00:00	Restored EF-2TA	No Impact
2	16:09:00	Failed EF-2TB	No Impact
	16:15:00	Restored EF-2TB	No Impact
3	16:35:00	Failed EF-2AA	No Impact
	16:43:00	Restored EF-2AA	No Impact
4	16:51:00	Failed EF-2AB	No Impact
	17:00:00	Restored EF-2AB	No Impact
5	17:15:00	Failed EF-2AA	Recovered
	17:25:00	Restored EF-2AA	Recovered
6	17:40:00	Failed EF-2AB	Recovered
	17:50:00	Restored EF-2AB	Recovered
7	18:00:00	Failed EF-3AA	No Impact
	18:10:00	Restored EF-3AA	No Impact
8	18:15:00	Failed EF-3AB	No Impact
	18:25:00	Restored EF-3AB	No Impact
9	18:30:00	Failed EF-2AA	No Impact
	18:37:00	Restored EF-2AA	No Impact
10	19:00:00	Failed AHU-13	Recovered
	19:10:00	Restored AHU-13	Recovered
11	19:30:00	Failed AHU-14	Recovered
	19:45:00	Restored AHU-14	Recovered

Questions



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