Containment Talk

J. Paul Jennette¹, Miguel A. Grimaldo², and John R. Henneman³

¹Cornell College of Veterinary Medicine, Ithaca, New York; ²University of Texas Medical Branch, Galveston, Texas, and ³The Pennsylvania State University, University Park, Pennsylvania

In this column, three of ABSA’s experts—“The Containment Guys”—in the areas of containment equipment and facilities operations answer questions about a variety of containment topics. Please e-mail questions on anything related to biocontainment facility design, operations, maintenance, and biosafety to Paul Jennette at ContainmentGuys@absa.org, Co-Editor Barbara Johnson at barbara.johnson@verizon.net, or Co-Editor Karen B. Byers at karen_byers@dfci.harvard.edu.

Directional Airflow—Where (and When) Do We Need It?

As we discuss containment issues in this column, we “Containment Guys” feel we need to reiterate the point Dr. Keene made in one of his last Applied Biosafety columns: The air in most containment spaces (unless the space serves as primary containment) is not normally “contaminated.” This is an important concept to remember as we begin to talk about directional airflow in this column.

Directional airflow is a fundamental component of containment, both in high- and maximum-containment labs, as well as equipment such as most Biological Safety Cabinets (BSCs). While we use or interact with it in many aspects of biosafety operations, directional airflow is often not well understood. Accordingly, questions related to directional airflow frequently arise, including:

- Where does directional airflow occur—between rooms or within rooms?
- If there is a pressure differential between two rooms, does that mean there is directional airflow between them?
- What is the best/appropriate/safe pressure differential for containment?
- What methods are available to assess directional airflow?
- Does it matter if a door is opened or closed when considering directional airflow?
- What factors affect directional airflow in facilities?
- How can we achieve directional airflow for a facility if we cannot ensure that the airflow between each room is directional?
- What about airflow reversals—when do they really matter?
- Do we need to be concerned about directional airflow in BSL-2 labs?
- What factors affect directional airflow in BSCs?

In the next couple of columns, we will provide answers to these questions. If you have additional questions about directional airflow (or any other containment topic), just ask the Containment Guys!

Where does directional airflow occur—between rooms or within rooms?

While some might think that we can make airflow directionally from one (maybe more “safe”) part of a room to another, this is not practical in most biological laboratories or animal rooms due to the multiple factors that create a relatively turbulent (i.e., well-mixed) environment in the room. The very nature of the ventilation supply and exhaust vents in most labs causes the air to be well-mixed in the room since they are typically point sources (meaning air enters from one point and exits from another point, usually on the opposite end of the room). The ventilation system would have to be arranged more like a wind tunnel (i.e., with the supply covering one wall and the exhaust covering the opposite wall) to create directional airflow across the room—this might be good for testing airplanes or race cars, but not for infectious disease research! Some may think it is a good idea to design the room like a very large biosafety cabinet…until they put equipment and personnel in the room—that’s when this idea goes out the window. Equipment in the room can contribute to air movement, either through the action of fans or blowers (e.g., the discharge of BSCs or cooling fans in refrigerated equipment) or by creating thermal convection plumes (e.g., incubators or autoclaves). Lastly, the lab’s occupants mix the air in the room as they move around.

So, really all we can rely only on directional airflow occurring between rooms, and we see the practical implications of this in our BSL-3 operations all the time. After all, we typically think of doorways as the boundary between the higher- and lower-risk areas in a containment lab, and we (hopefully!) don’t have situations where BSL-3 workers think they need respiratory protection in one part of a room but not in another.

If there is a pressure differential between two rooms, does that mean there is directional airflow between them?

Creating a pressure differential between two rooms is one way to cause directional airflow to occur between two rooms, and differential pressure is commonly used to indicate directional airflow at doorways in containment facilities. While they are related (one can cause the other), they are not the same and the relationship between them depends on another factor. You can do a simple experiment right now to demonstrate this relationship (caution—do this at your own personal risk…):  

1. Take a deep breath and sigh or yawn quickly through your mouth. In doing so, you created directional airflow out
of your mouth and you (probably) did not feel any resistance since your mouth was open.

**Lots of airflow but no differential pressure.**

2. Now do the same thing, but purse your lips as if whistling or blow out the candles on a birthday cake and try to move the air out of your lungs quickly. Did you feel a difference? You probably felt resistance caused by your mouth not being open as much.

**Plenty of airflow but some differential pressure.**

3. Once more—this time, grimace and try to blow the air through your clenched teeth. Did you notice that you had to work harder and it took longer to exhale completely?

**Less airflow and more differential pressure.**

4. Last time—close your mouth tight and try to push that lungful of air out between your lips. Did your cheeks puff out?

**No airflow but lots of differential pressure.**

As you just experienced, airflow and differential pressure are related but that relationship depends on the area of the opening through which the air is flowing. That relationship is exponential—for the same airflow, the differential pressure goes up by the square of the decrease in the area (this is why it got harder and harder to move that lungful of air out as you closed your mouth).

In a containment lab, the ventilation system controlling the airflow between two rooms is analogous to your lungs and the doorway is analogous to your mouth. When the door is wide open (step 1), lots of air can flow through the doorway but the differential pressure between the rooms is essentially zero. When the door is closed, but not tightly so (step 2), perhaps due to a transfer grill in the door, a substantial amount of airflow can move through the doorway with a measurable pressure differential. If the door is tightly, but not completely, sealed (step 3), much less airflow can move through with the same pressure differential. Of course, if the door is completely sealed (step 4), no airflow occurs regardless of the pressure differential.

The bottom line message here is: For a given airflow, the pressure differential across a closed doorway can be anything you want it to be, depending on how tightly the door is sealed. (The reverse is also true—for a given pressure differential, the airflow across a closed doorway can be anything you want it to be, depending on how tightly the door is sealed.) For two very different doors (but commonly used in containment labs)—one with no seals and one with full perimeter gaskets and a solid sweep—the pressure differential across the doors could be exactly the same, but the airflow would be very (exponentially) different. Understanding this relationship is critical to understanding the nature of containment laboratories—if you need help with this, just write to the Containment Guys!

**What is the “best,” “appropriate,” or “safe” pressure differential for containment?**

This question comes up all too often, and the answer is that most common answer in Biosafety...“It depends!” As we demonstrated above, the differential pressure at a doorway is dependent on both the amount of airflow moving through the doorway and the amount of open area through which the air is flowing. A value of 0.05” w.g. (“w.g., inches of water gauge, a measurement of pressure based on a water-filled manometer reading) is commonly used in the United States (the corresponding metric pressure is 12.5 Pascals). Why is this value used? The reasons have to do mostly with historical precedent, door operability, and automated control parameters, but we simply cannot say that 0.05” (or any pressure value) is best, appropriate, or safe for containment. Instead, the question should be “What airflow is best, appropriate, or safe?” While we can make generalizations, the answer depends on many, often site-specific, factors.

**What methods are available to assess directional airflow?**

There are multiple methods to assess directional airflow. The most commonly used method when testing a facility is the smoke test. Smoke can be generated multiple ways (chemical reaction tubes, theatrical fog machines, incense sticks, and other methods—some may wish they could justify importing Cuban Cigars for this...). Other more sophisticated methods include the use of metering equipment for airflow velocity or the use of tracer gases. As explained previously, differential pressure does not always correlate exactly with directional airflow, but differential pressure monitors are commonly used to assess the potential for directional airflow between spaces. Other equipment to indicate directional airflow includes “ping-pong ball” style devices, but these can become stuck in place by dust particles. In our opinion, nothing beats using magnetic tape from an old 8-track cartridge suspended in the airflow, but that just shows our age. Any thin flexible material can be used when other visual indicators are not available.

If you want to know more, would like to make a comment, or have other questions to ask, please send a note to the Containment Guys!

**Additional Reading**
