Ventilation Rates, Room Pressure Control, and Energy Costs

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Introduction
The purpose of this paper is to discuss the impact of laboratory ventilation rates and pressure controls on users and designers. Laboratory ventilation rates and directional airflow via pressure control are necessary safety measures taken to protect lab occupants and the general public. However, because most containment scenarios require 100% outside air systems with 100% exhaust, additional airflow requires conditioning large volumes of outside air and drastically increases facility energy use. Furthermore, advanced control scenarios have significantly higher initial costs to implement. Ultimately, laboratories are built to budgets; design flexibility is therefore somewhat limited and requires the designer to balance control and ventilation strategies.

“The ventilation system of a high containment laboratory is central to its performance and operation and the ultimate key to ensure that the environment is safe for human occupants, research animals and the environment.” 1 The ventilation system achieves two distinct functions: dilution and removal of contaminants through increased ventilation rates, and containment of contaminants through directional airflow control.

The following sections will explore ventilation rates, pressure control, and the energy use and cost implications of design decisions.

Laboratory Ventilation Rates
As mentioned previously, ventilation performs the function of diluting and removing contaminants. Dilution ventilation is a method of using high volumes of air to dilute contaminants in the lab space. While more effective than a recirculating air handling system, the air in rooms served by a dilution ventilation system is not completely exchanged at any time; the contaminated air is simply mixed and remixed with clean air, reducing the density of contaminants within the space. Many labs use source removal, such as fume hoods, biosafety cabinets (BSCs) and snorkel exhaust systems instead to capture and exhaust contaminants at their source, preventing them from ever entering the general lab space.

There is no prescriptive requirement for ventilation rates; instead, performance-based approaches are now preferred, typically based on a minimum air changes per hour (ACH) value. Different standards require different ACH values; NFPA set the bar between 4 and 8 ACH, OSHA suggests 4-12 provided that capture hoods are utilized as the primary method of control, the IBC requires 1 CFM/ft² (equivalent to 6 ACH in a room with 10 foot ceilings), the NIH has a minimum of 6 ACH, and the ASHRAE HVAC Applications handbook states that while 4-8 ACH appear to significantly reduce airborne contaminants, anything above 12 ACH produces diminishing returns.

Directional Airflow and Room Pressure Control
While many standards are willing to suggest minimum ACH requirements, ANSI Z9.5 instead states that while helpful, an air change rate cannot be specified for design that is guaranteed to provide safe operating conditions at all times. Instead, the standard suggests directional airflow be the primary design instrument of containment. The basic methodology behind directional airflow states that clean air flow into dirty spaces, and when you have multiple dirty spaces, the air flows from the cleanest to the dirtiest, and is then exhausted.
The designer must take into account the intermediate spaces this “dirty” air may flow through, and ensure that occupants of that space are properly protected. In order to create these airstreams, the spaces are operated at different pressures, so that air in a higher pressure space naturally flows into a space with lower pressure. Typically, these spaces are referred to as being “positive”, “neutral”, or “negative”, with varying degrees of positivity or negativity depending on the number of steps that the air must cascade through.

The pressure difference is created by exhausting more air than is supplied to the space, forcing additional air to flow from adjacent spaces to make up the difference (a basic conservation of mass situation: if more air is removed than is supplied, there cannot be a “void” of air, more air from other spaces will be brought in to fill the space). Control valves on the supply and exhaust ductwork within the space modulate to maintain this air differential. Pressure control can be achieved in a number of ways. Pressure sensors can measure the pressure in each space and report to the valves whether more or less air is required to maintain the differential. While actual pressure differential values (the difference in pressure between two adjacent spaces) is not mandated in most guidelines, most designers aim to maintain at least 0.05” water column difference between two spaces. Rather than use pressure sensors, some designers instead design a flow offset into the airflow control valves, so that as one valve modulates, the other modulates with it to maintain the difference in airflow into the room. This value can either be a percentage difference between the two airflows (15% is typical), or a set “CFM per door” design that ensures a significant volume of air (approximately 50 CFM) is passing through all doors in static situations. In most situations, 50-100 CFM difference between the supply and exhaust is adequate to ensure pressure differential is maintained.

In order for air to flow into the negative spaces, there must be a path for it to follow. In lower-containment facilities, this makeup air can flow through cracks around the door into the space. If the air volume exceeds what can easily pass through this space, or if additional containment is required, engineered leaks should be employed. These can be as simple as grille in the door, a barometric damper in a wall grille, or as complex as a dedicated HEPA filter assembly matching those serving the supply and exhaust air systems.
Energy Use and Cost Implications

One major impact of using 100% outside air in ventilation systems is the added energy costs. Especially at outdoor temperature extremes (summer and winter) the cost to condition the air to appropriate supply air temperatures (and to dehumidify in less arid climates) can escalate very quickly. In most ACH scenarios, the supply air volume dictated by the ACH requirement exceeds the airflow that would be required to simply condition the space, so added reheat may come into play to prevent the room from becoming uncomfortable cool in the summer.

An energy study was performed by several of our colleagues to determine whether the percentage offset approach or the “CFM per door” approach yielded better energy conservation in an ambiguous lab modeled in Trane Trace. The analysis was conducted in four major US cities with distinct climates - Atlanta, Denver, Seattle, and Minneapolis – and the results were compared for each. This whitepaper cannot do their study justice, thus a link has been provided in the endnotes, but the conclusions were that location has the largest impact on energy costs, with some savings being seen in the offset systems within those more advantageous locations.

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