Space Pressurization:
Concept and Practice
ASHRAE Distinguished Lecture Series

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Agenda

Introduction (concept, purpose, uses, scope)
Physics: Infiltration and Containment
Pressurization Methods
Design Steps
Contaminant Control Perspective
Summary
Room Pressurization

A ventilation technology that controls migration of air contaminants by inducing drafts between spaces.

Exhaust system removes air
Supply system delivers less
Room pressure is negative
Infiltration makes up the difference
Inward air flow contains pollutants
Introduction: Who uses it? Why?

Biological and Chemical Laboratories
- prevent spread of airborne hazards

Hospital Isolation Rooms
- protect patients and staff from germs

Hospital Pharmacies
- facilitate sterile compounding

Clean Manufacturing
- maintain product quality

Introduction: Who else uses it?

Office towers
- control smoke in a fire; maintain exit path

Any Building
- separate rest rooms from other spaces

Restaurants
- keep kitchen smells out of the dining room

Any Building
- keep unconditioned OA out of occupied spaces

These uses are out of today's scope
How is success defined?

Success is control of contaminants, not flows and pressure values.

Infiltration and Containment

- Infiltration: mechanical process
- Velocity, Area, Pressure
- Infiltration Curves
- Importance of the Envelope
- Select Pressurization Level
- Specifying the Envelope
Infiltration Process: Pressure, Velocity, Area, Flow

Infiltration is a physical process
Pressurization is an engineered result
ASHRAE Handbook and Ventilation Manual from ACGIH model the process

Pressure vs. Velocity

Simple approach is to model the velocity with a discharge coefficient
ACGIH Industrial Ventilation: 7-3

\[ v = 0.6(4000)\sqrt{\Delta P} \]

ASHRAE Fundamentals Handbook presents more complex model, but the result is nearly the same
**Infiltration Model for Pressurization**

Air velocity through gaps in envelope controls contaminants. Velocity related to pressure by orifice flow. Transfer flow and HVAC flow difference is leak area times velocity.

**Reality of Room Air Motion**

Photograph of flow field (2D) in cross section of a room. “Particle Image Velocimetry” by Zhao L., ASHRAE Transactions, DA-07-044.
Velocity and Leakage Area

Flow is velocity times area

\[ Q = 2610A\sqrt{\Delta P} \]

- \( Q \) = infiltration flow, cfm
- \( A \) = leakage area, sqft
- \( \Delta P \) = pressure across envelope, inwc

Infiltration Curve – Pressure Difference vs. Flow
Infiltration Curves for Several Values of Leakage Area

Importance of the Envelope

Leakage area is the main mechanical parameter in the pressurization system. Like knowing the hx characteristics to apply a heating coil. Like knowing the pipe diameter in a hydronic system.
Select Pressurization Level

Choose the flow offset
Let it determine the pressure

Select Pressurization Level

Choose the pressure
Let it determine the flow offset
Select Pressurization Level

Different ways to express the level of pressurization
- in terms of the pressure difference
- in terms of the infiltration flow

“Specify either the pressure
or the flow offset, not both.”

Unless you are trying to specify the envelope

Pressurization and Migration

Positive room pressure
- drives air and contaminants out

Negative room pressure
- draws air and contaminants in

Neutral room pressure
- exchanges air and contaminants in both directions
Pressurization via HVAC

Control Methods Explained and Compared
- Differential Flow Control
- Pressure Feedback
- Cascade Control

Selecting a Pressurization Control Method
- How Tight is Tight?
- Required Pressure Relationships

Control Methods Compared

Three widely published methods
- Space pressure feedback
- Differential flow control
- Cascade control

References:
- 2011 ASHRAE Handbook, HVAC Applications. Chapter 16 Laboratory Systems
- Siemens Building Technologies: Doc #125-2412. Room Pressurization Control
Control Methods Compared

Some other ways
- Adaptive leakage model
- Trim valve

References:
- W Sun, ASHRAE Transactions, NA-04-7-2. Quantitative Multistage Pressurizations in Controlled and Critical Environments

Pressure Feedback
Pressure Feedback

Measure pressure difference across room boundary
Compare to selected setpoint
Adjust supply flow or exhaust to maintain pressure difference

Differential Flow Control
Differential Flow Control

Carefully control air supply to room
Carefully control all exhaust from room
Enforce a difference between them
Select the size of difference
to reliably contain pollutants

Cascade Control
Cascade Control

Has other names:
- “adaptive offset” “DP reset”

Measure pressure difference across room boundary
Compare to selected setpoint
Control supply and exhaust flow
Enforce a difference between them
Dynamically adjust flow difference to maintain the pressure setpoint

Selecting a Control Method

Factors affecting selection
- Tightness of envelope
- Number of pressure levels needed
- Speed of disturbances and response
- Duct conditions for flow measurement

Reference:
2011 ASHRAE Handbook – HVAC Applications,
Chapter 16 - Laboratory Systems, page 16.12
Tightness of Envelope

Infiltrating Air Flow

Pressure Difference

Number of Pressure Levels

Relatively simple requirement
2-levels, OK for Differential Flow Tracking
Number of Pressure Levels

Indicate intended relative pressure levels

Effect of Air Flow Errors, In and Out

Numerical illustration

<table>
<thead>
<tr>
<th></th>
<th>Nominal value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust flow</td>
<td>1000</td>
<td>+/- 100</td>
</tr>
<tr>
<td>Supply flow</td>
<td>850</td>
<td>+/- 85</td>
</tr>
<tr>
<td>Transfer flow</td>
<td>150</td>
<td>+/- 185</td>
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</table>
Select Pressurization Level

Based on leakage area
Example: 150 cfm for ½ square foot

Select Accuracy Target

Based on need to control contaminants
Not product spec's
### Derive Flow Control Accuracy

#### Numerical illustration
Base flow control accuracy on desired infiltration
ANSI Z9.5, Laboratory Ventilation

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<tr>
<td>Transfer flow</td>
<td>150</td>
<td>+/- 45</td>
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#### Derive Flow Control Accuracy

Consider accuracy across range of flow values
Pressurization specs easier to meet at low flow

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Pressurization and Contaminant Control

Theory: net inward flow blocks contaminants
Recent research relates pressurization to contaminant control
- ASHRAE research relates pressure to clean room contamination: RP 1344 and RP 1399
- Bio lab experiments: Bennet, Applied Biosafety, 2005
- Isolation room research, Tang, et al.
Success is control of contaminants, not flows and pressure values
Fact: contaminants cross boundaries for many reasons
It’s like baseball

Even if the wind’s blowing in, sometimes stuff gets out.

Pressurization and Contaminant Control

Contaminant control can be very important or only slightly important. Biosafety standards recognize range of hazards and range of responses. Engineering and commissioning should match effort and solutions to needs.
Levels of Contaminant Control

Pressurization is one tool
Physical barrier is also

- BSL 1 – Laboratories should have doors
- BSL 2 – Doors should be self-closing
- BSL 3 – Series of two self-closing doors
- BSL 4 – Airlock with air tight doors

Summary

Space pressurization: tool for contamination control, not a ‘magic shield’
Envelope leakage is main mechanical parameter
Several HVAC control methods
  - Differential flow control is used most often
  - Choice usually driven by envelope
Derive air flow accuracy spec from pressurization
Align engineering effort with the hazard
Thank you!
Questions?

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