Safe humidification?
Humidified Buildings Cold Climates
Mold when it’s hot and humid, out
Condensation in the enclosure - Hot and humid outside
Mold in a wall cavity – outdoor air accidentally drawn into wall from attic by return plenum leaks.
Calendar acts as accidental vapor retarder on cool side of wall during cooling conditions
Design to Dehumidify

Design HVAC using ASHRAE Humidity Control Handbook
Correctly Sized AC Cools and Dehumidifies

OA Temperature
OA RH
Indoor Temperature
Indoor RH
OA HR
Indoor HR
2X oversized AC cools but does not dehumidify

OA Temperature
OA RH
Indoor Temperature
Indoor RH
OA HR
Indoor HR
HVAC Design

Equipment Design

• 55°F indoor dew point

• Use ASHRAE peak outdoor dew point for humidity control design (not peak temperature)

• Don’t oversize cooling—it leads to major problems

Air-side Design

• Exhaust humid air and provide DRY makeup air

• Avoid plenums—Use sealed duct work instead

• Seal ALL duct connections, using mastic

Moisture Guidance from U.S. EPA
Meet ASHRAE 62.1 air handler design criteria

Air handlers and ductwork inside the enclosure
ASHRAE peak dew point design data

Figure 2-17  Peak Dew Point Data are Available in the Climatic Design Information Chapter of the ASHRAE Handbook—Fundamentals
Moisture Control Principles For Construction

1. Things get wet during construction - That’s life. But the building must dry out.

2. Understand the purpose of moisture-related design details.

3. Installation is often more important than design.

4. The sequence of installation matters—a lot.
Construction

Planning

• Provide rain-protected storage for wall board
• Trade coordination meetings for air and water barrier installation sequence

Installation

• Pressure-test plumbing, air ducts and roof-wall air barrier joint BEFORE interior walls and ceilings are installed.
• Dry out concrete and masonry block before walls are installed.
Moisture Control Principles For Operation and Maintenance

1. Principles are less useful for maintenance personnel than component-specific checklists. Generate checklists and use them:
   a. Site and foundation drainage
   b. Walls and roof leaks
   c. Plumbing leaks and HVAC filters
## Troubleshooting checklist

<table>
<thead>
<tr>
<th>SYMPTOMS</th>
<th>MOISTURE PROBLEM</th>
<th>POTENTIAL CAUSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold growth</td>
<td>Leaks in the building enclosure due to problems with rain and groundwater controls</td>
<td>Missing or poorly designed details</td>
</tr>
<tr>
<td></td>
<td>Insufficient dehumidification by HVAC system</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Condensation on dirty surfaces inside HVAC systems</td>
<td>Poor condensate drain design</td>
</tr>
<tr>
<td>Wet materials enclosed in building assemblies</td>
<td>No values for moisture content or emission given in the specifications</td>
<td></td>
</tr>
<tr>
<td>Peeling paint</td>
<td>Leaks in the building enclosure due to problems with rain and groundwater controls</td>
<td>Missing or poorly designed details</td>
</tr>
<tr>
<td>Wood decay</td>
<td>Improper design</td>
<td>Incorrect sloping</td>
</tr>
<tr>
<td>Corrosion</td>
<td>Improper installation during construction</td>
<td>Damaged sub-grade drainage</td>
</tr>
<tr>
<td>Plumbing leaks and spills</td>
<td>Improper operations and maintenance practice</td>
<td>Defective pipe joining</td>
</tr>
<tr>
<td>Water travels to materials that cannot tolerate wetting</td>
<td>Capillary action (water wicks through porous building materials such as concrete or wood)</td>
<td>Accidental penetration of slope by one or more drywall screws</td>
</tr>
<tr>
<td></td>
<td>Moisture barrier omitted from building design</td>
<td>Drainage layer beneath slab omitted from building design</td>
</tr>
<tr>
<td></td>
<td>Moisture barrier not installed during construction</td>
<td>Drainage barrier not installed during construction</td>
</tr>
</tbody>
</table>
Operation and Maintenance

Drainage

• Keep water away from the foundation (rain leaders and finish grading)
• Make sure irrigation does not spray the building or puddle at the foundation

HVAC + Plumbing

• Install clean outside air filters (monthly)
• Check damper positions and adjust outdoor air flow (annually)
• Drips and condensation matter—fix them and dry up any water
Summarizing Guidance from EPA

1. Each stage of design, construction and operation has specific decisions that increase—or reduce risk of problems.

2. Design
   a. Foundation drainage including roof rain runoff management
   b. Walls with rain screen, water barrier and pan flashing for windows
   c. Peak ASHRAE dew point for ventilation system design

3. Construction
   a. Rain-protected storage
   b. Subcontractor coordination for water/air barrier/flashing installation
   c. Pressure-test systems before installing interior walls and ceilings
Making Buildings Airtight

- Identify a target air tightness level
- Design to make them airtight
- Training, inspection, and quality assurance programs
- Conduct intermediate and final pressure testing
- Fix it and retest as needed
Design

- Identifying air barrier locations
- Making it easy/making it hard
- Air barrier materials and systems
- Provide details and specifications illustrating air barrier continuity at joints and penetrations
- Specify inspections, qualifications, QA and intermediate and final testing
- Air Barrier Association of America (ABAA)
  - Manufacturers
  - Contractors
  - QAP
- Assess section for condensation and drying potential, given climate and internal loads.
Air Barrier Association of America

- Understand the concept of Air Barrier Systems
- Design Air Barrier Systems
- Specify Air Barrier Systems in your Building Enclosure
- Locate Manufacturers and Distributors of Air Barrier Materials
- Locate Contractors who Install Air Barrier Assemblies and Systems
- Incorporate ABAA’s Quality Assurance Program into your Project
- [http://www.airbarrier.org/index_e.php](http://www.airbarrier.org/index_e.php)
Level 1 Tested air barrier shown in red

- ○ Doors Closed During Test
- ○ Outdoor Shell Pressure Taps

Wright-Patterson Air Force Base
Human Performance Wing
South Building Fan Pressure Test
interior wall must be made air tight between High School and Media Center must be made air tight

fluid applied membrane on CMU

Fluid applied membrane on gypsum sheathing

Location of air barrier around Media Center
spray applied membrane makes air barrier on CMU and laps over Detail Tape on metal angle

Perm-A-Barrier Detail Tape w/ surfaces primed per manufacturer

Perm-A-Barrier Detail Tape adhered to back of roof Vapor barrier allows air barrier to slide in expansion joint

self-adhering roof vapor barrier connects roof vapor barrier to steel angle

self-adhering roof vapor barrier loops down in gap between roof deck and masonry wall (all joints sealed)

EXTEND ROOFING MEMBRANE UP FLYWOOD FACE, FULLY ADHERED

MORTAR NET

MASONRY BACKUP. REFER TO PLANS AND STRUCTURAL DRAWINGS

5/8" X 5/8" MASONRY STUDS. SECURE TO MASONRY AT 12" O.C.

2" X 6" WOOD FRAMING AT 24" O.C. FULL VOID WITH BATT INSULATION

2" X 6" WOOD CLEAT CONTINUOUS BETWEEN VERTICAL STUDS. SECURE TO MASONRY AT 24" O.C.

CONTINUOUS AIR BARRIER BY G.G. PROVIDE 6" LAP SPlice AT VAPOR BARRIER TRANSITION.

2" X 6" TIMBER FLYWOOD. FULLY ENCAPSULATED WITH FRAMING. INSTALLED BY ROOFING CONTRACTOR.

2" X 6" WOOD FRAMING AT 24" O.C. FULL VOID WITH BATT INSULATION

LL REINFORCING PLATE SECURED TO MASONRY BACKUP. COORDINATE WITH STRUCTURAL DRAWINGS.
Get it in the specs

- Division 01: general requirements for hygrothermal control; coordination; testing
- Division 03; 04, 06, 09 concrete, CMU, sheathing surface prep
- Division 07; dampproofing, waterproofing, air barriers, vapor retarders, roofing, flashing, thermal insulation, sealants
- Division 08; doors, hatches, skylights, windows
Field Visits

- Kick-off: air barrier and moisture control requirements, mock-ups, inspections and tests described to all parties
- Inspections: General, subs, third party
- Mock-ups – inspection, testing
- Final Airtightness Test
Inspections and QA

- Commissioning agent - periodic
  - Completed work and work in progress
  - Observe or conduct QA tests on installed material
  - Examine work logs

- Prime Contractor QA personnel – daily inspections

- Sub-contractors
  - Daily inspections, QA tests and documentation
Testing: what needs to be specified?

- Qualifications of testing agency
- What must be provided by the contractor
- The purpose of the test
- Test Method
- The target specification
- The boundaries, location, sampling procedure
- Conditions that must be met before a test can be conducted
- How the test result is interpreted:
  - Confidence intervals
  - Passing/failure
  - Report-retest?
<table>
<thead>
<tr>
<th>Required enclosure function testing E2813-12 (black enhanced only, red enhanced and fundamental, blue fundamental only)</th>
<th>Laboratory test</th>
<th>Mock-up</th>
<th>In-situ field test</th>
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<td>ASTM E966, E1014, E1503</td>
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<tr>
<td>Water penetration</td>
<td>ASTM E331</td>
<td>ASTM E1105; AAMA 501.2</td>
<td>ASTM D5957, E1105; AAMA 501.1, 501.2</td>
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<tr>
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<tr>
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<td>AAMA 508-07</td>
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<tr>
<td>Security</td>
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</tbody>
</table>
QA testing
Air Barrier Association of America

ABAA QAP Program
• Based on ISO9000
• Standards and specifications
• Product evaluation and acceptance
• Contractors accredited
• Certification of installers
• Daily inspections, tests and logs
• Third party Field audits
Inspections are crucial
Intermediate test
Planning and Conducting a Whole Building Airtightness Test

- Planning
- Prepare the building
- Setup equipment and conduct test
- Analyze data
- Write the report
Fan Pressurization Airtightness Test

Induced pressure difference

Mass flow in

Mass flow out
Regression analysis on
Transformed Nonlinear Function: \( (E779) \)
\[ Q_{\text{cfm}} = C*(\Delta P_{\text{pascals}})^n \]

Where
- \( C \) = flow coefficient
- \( n \) = flow exponent \( (0.5 \leq n \leq 1.0) \)

If it takes three fans to get to 25 Pascals it will take less than three to get to 50.

This is a simplification. Air density and viscosity also affect flow and the leakage curve really isn’t a power law.
Repeated Tests at the reference induced pressure difference. E1827
Planning

- New, unoccupied buildings/Occupied buildings
- Identify parties
- Select date
- Identify Test Enclosure Boundaries
- Identify HVAC equipment that must be turned off and penetrations that must be sealed
Identify Parties

- Owner
- Building Management
- Security – determine security procedures to protect property and privacy
- Health and Safety
- Fan testing team
- HVAC control person (contractor or in-house)
Select Date

- When the fewest people are in the building – weekends, holidays
- During the test you need:
  - Access to all rooms, mechanical rooms, locations where HVAC penetrations must be masked
  - HVAC controls contractor
  - Power for test fans
Test Enclosure Boundaries, Airflow Needed and Fan and Pressure Tap Locations

- Double check boundaries and enclosure areas specified in design drawings
- How much air do I need?
- Inspect the geometry for interior barriers to good pressure distribution
- Locate fans to provide uniform pressure distribution
- Locate interzonal pressure taps to document uniform pressure distribution
Sketchup models to identify test enclosure location and areas
How much air do I need?

- **Maximum leakage rate specified**
  - Bring enough to induce the specified pressure difference with the specified flowrate
  - E.g. Area enclosure (ft²) x 0.25 cfm/ft² at 75 pascals (ACE spec)
  - 0.6 ACH x enclosure volume (ft³) / 60 m/hr (passiv haus)

- **Ordinary construction**
  - 0.2 – 1.2 cfm/ft² at 75 pascals; ?
NOW PLAYING IN IMAX
MARCH OF THE PENGUINS
35 MM G
MYSTERIES OF EGYPT NR 2D
WWW.CINEMARK.COM
Prepare the Building

- If the whole building is one test zone
  - Close exterior doors and windows
  - Open interior doors
- If the test zone is a portion of the whole building
  - Close exterior doors and windows
  - Isolate test zone from surrounding building
    - Close doors
    - Tape off supply diffusers and return grilles that connect to ducts or equipment outside the test zone
  - Determine whether adjacent zones should be open to outdoors or closed
- Close or mask outdoor air intakes and exhaust outlets
  - Dampers
  - Gravity dampers
  - Plastic, foam board and tape
Block interior doors open
In occupied buildings this may present an unacceptable security issue
Identify and seal HVAC related enclosure penetrations

- Intention...
- Outdoor air intakes
- Exhaust systems
- Passive relief
- Steam vents
- Dampers: Motorized, gravity, none
- Fan runs continuously?
- Elevator vents and kitchen range hoods – no dampers
Fans off
Dampers closed
No dampers, gravity dampers, motorized dampers, masking?

During pressurization tests gravity dampers blow open.
Interzonal Pressures

- Measure to check for pressure uniformity
  - Identify Suspected Pressure Drops
  - Measure or Monitor Interior pressure differences
- USACE and ASTM E779 require no two spaces differ by more than 10% of test pressure (wording not clear)