ASHRAE Iowa | SuperTech 2025

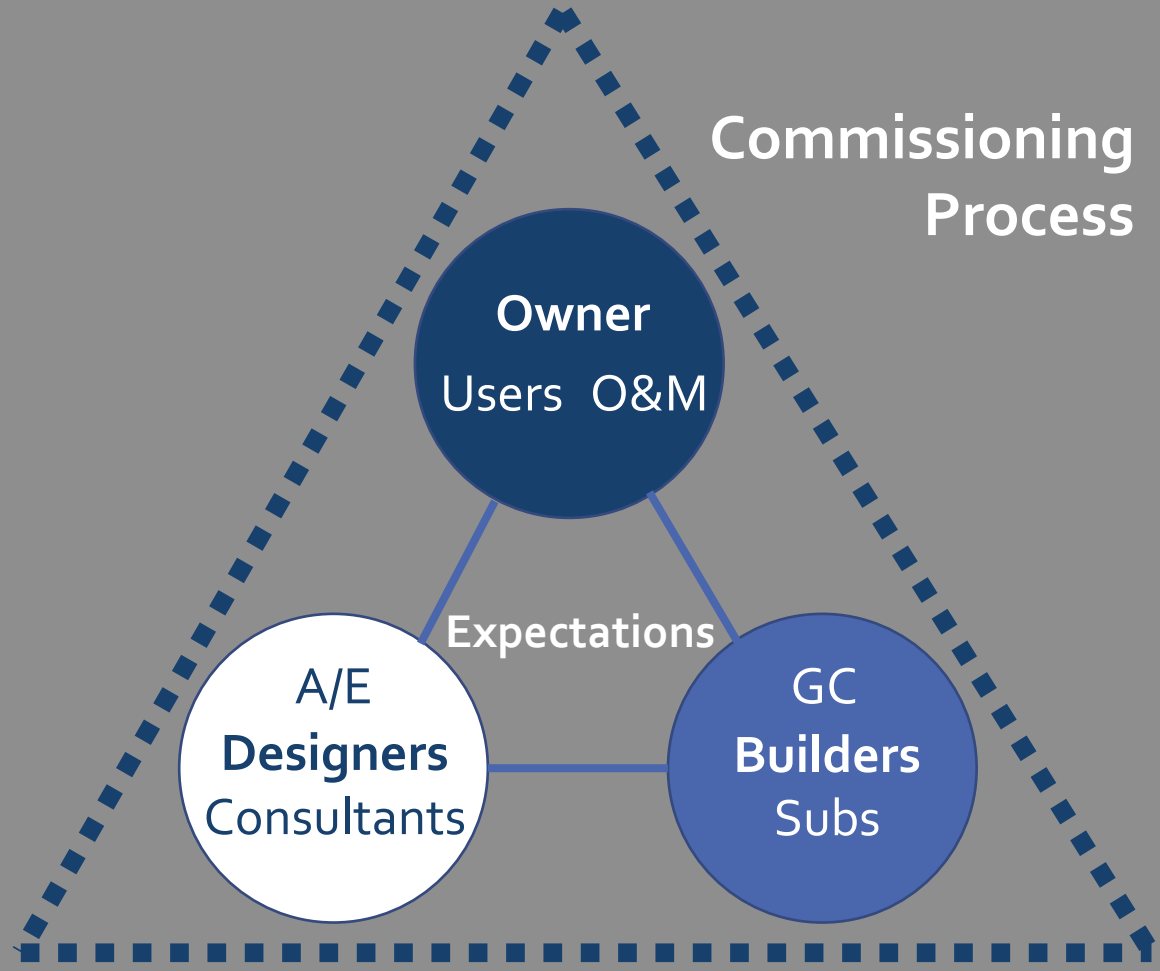
BUILDING ENCLOSURES: COMMISSIONING, CONTROL LAYERS, & THE INTERSECTION WITH HVAC

WHAT TO EXPECT TODAY

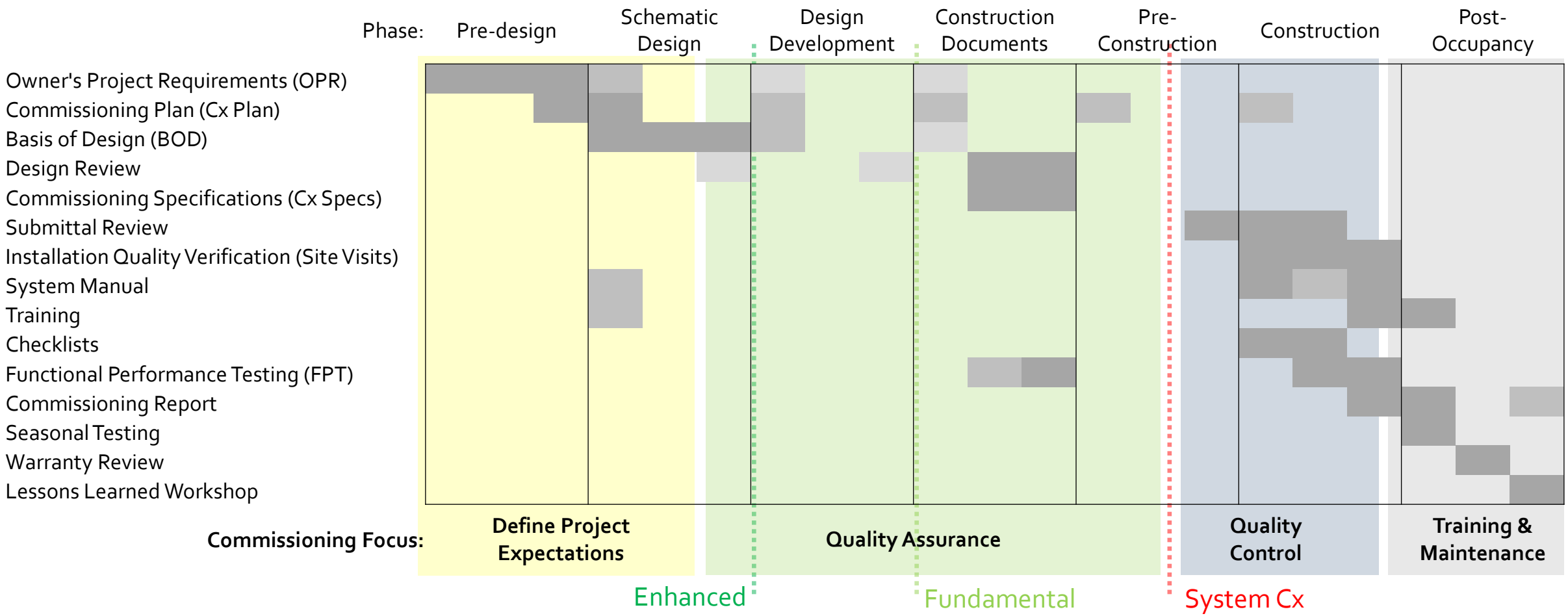
- Commissioning
  - Background
  - Differences & Similarities w/ Cx & BECx
- Building Enclosure Performance
  - Environmental Loads
  - Driving Forces
  - Control Layers
- Case Studies: HVAC related Enclosure issues
- ASHRAE 160

COMMISSIONING: WHAT IS IT

A structured **quality process** (assurance & control) intended to ensure that a building, when delivered, meets the **owner's requirements**



COMMISSIONING: ATTRIBUTES & SCHEDULE



BUILDING ENCLOSURE PERFORMANCE

Building as Environmental Separator

- Environmental Load (i.e. what are we concerned about separating)
- Driving Forces (i.e. why would it need to be separated)
- Control Layers (i.e. how do we manage the separation)

ENVIRONMENTAL LOADS

MOISTURE

- Bulk Water (Liquid): Large groups of molecules stuck together
- Vapor (Gas): Individual or small groups of molecules stuck together
- Solid
- Absorbed

AIR

- ~78% N_2, 21% O_2, 1%Ar,….

HEAT (Energy)

OTHERS

- Fire (Wildland-Urban Interface), Earthquake, Insects, UV, etc.

MOISTURE SOURCES

- Rain (including groundwater, flood water, etc.)
- Plumbing / plumbing leaks
- Interior vapor (generated by occupants & occupant activities & equipment)
  - Natatoriums
  - Museums
  - Medical Facilities
  - Electronic Equipment Rooms
- Exterior vapor (atmospheric)
- Meltwater (snow & ice)
- Construction moisture (built-in)

DRIVING FORCES

2nd law of thermodynamics

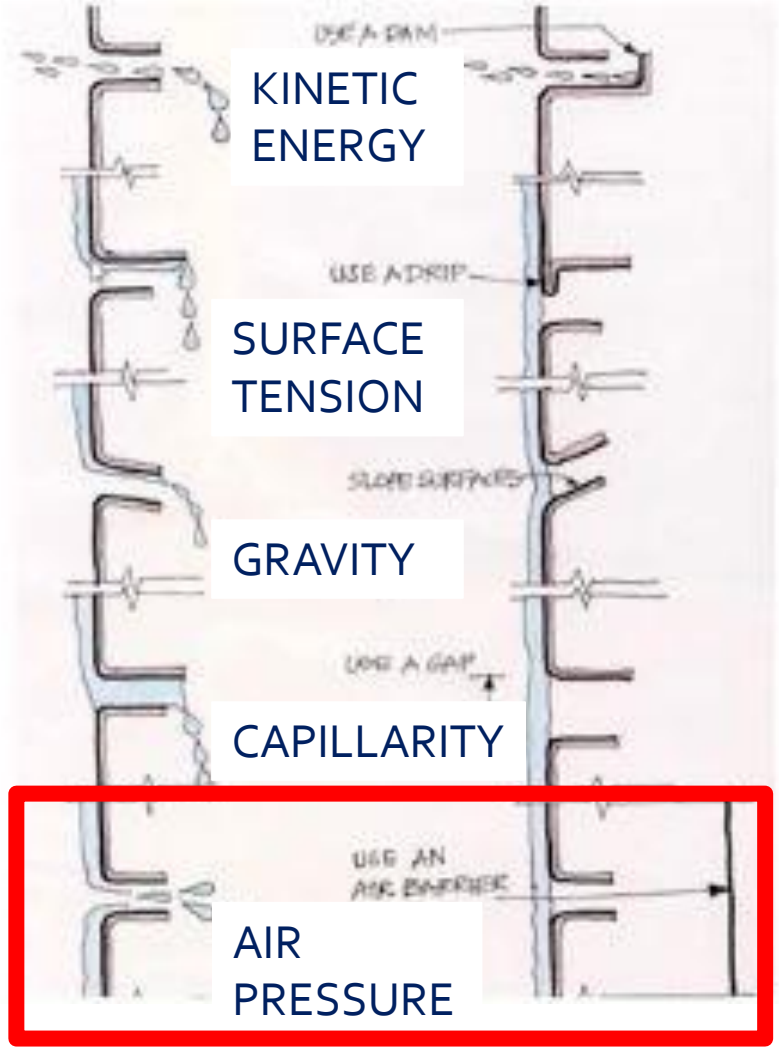
- Entropy always increases
  - As energy is transferred or transformed, its ability to do relative work decreases

Gradients

- Thermal gradient
  - Heat flows from Hot to Cold
- Concentration gradient
  - Water flows from more to less
- Pressure gradient
  - Air flows from higher to lower air pressure
  - Vapor flows from higher to lower vapor pressure (generally following temperature gradient)

BULK/LIQUID **WATER** TRANSPORT

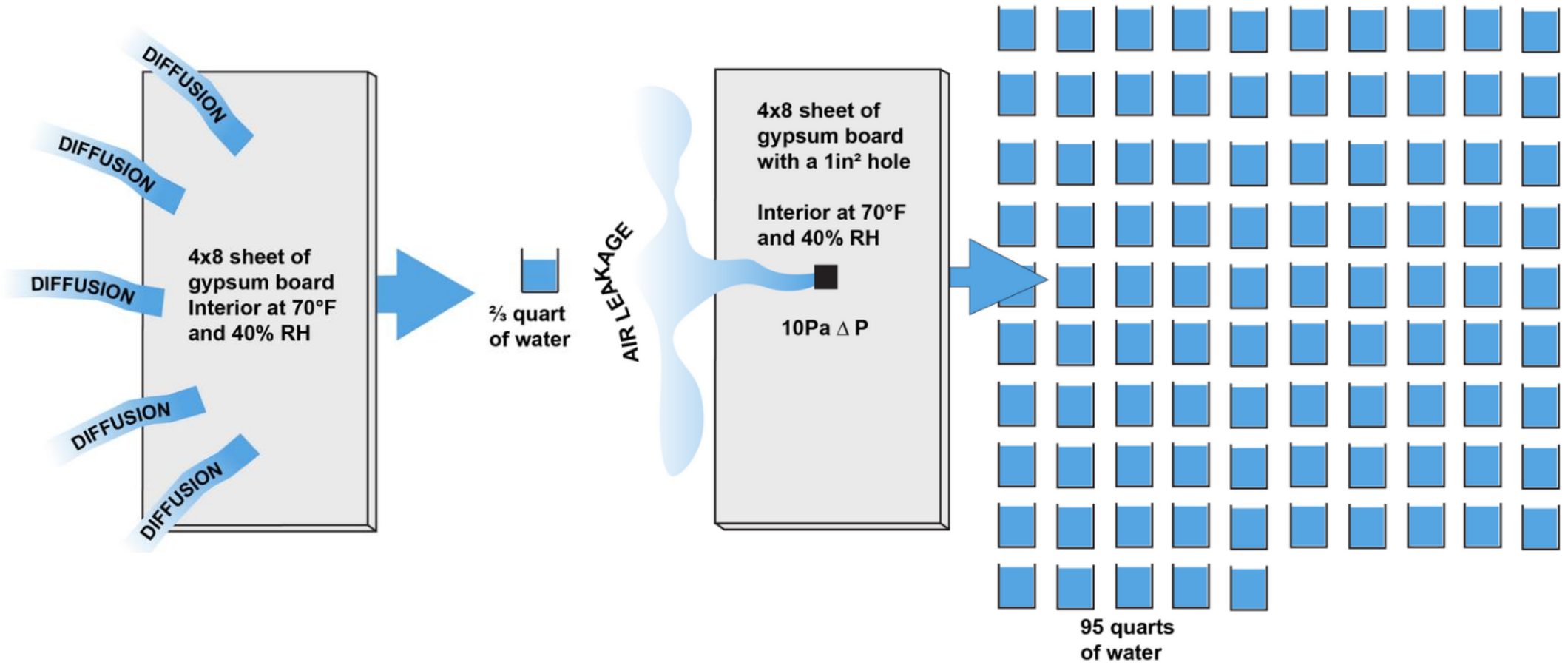
Forces Driving Water Through the Building Facade



WATER **VAPOR** TRANSPORT

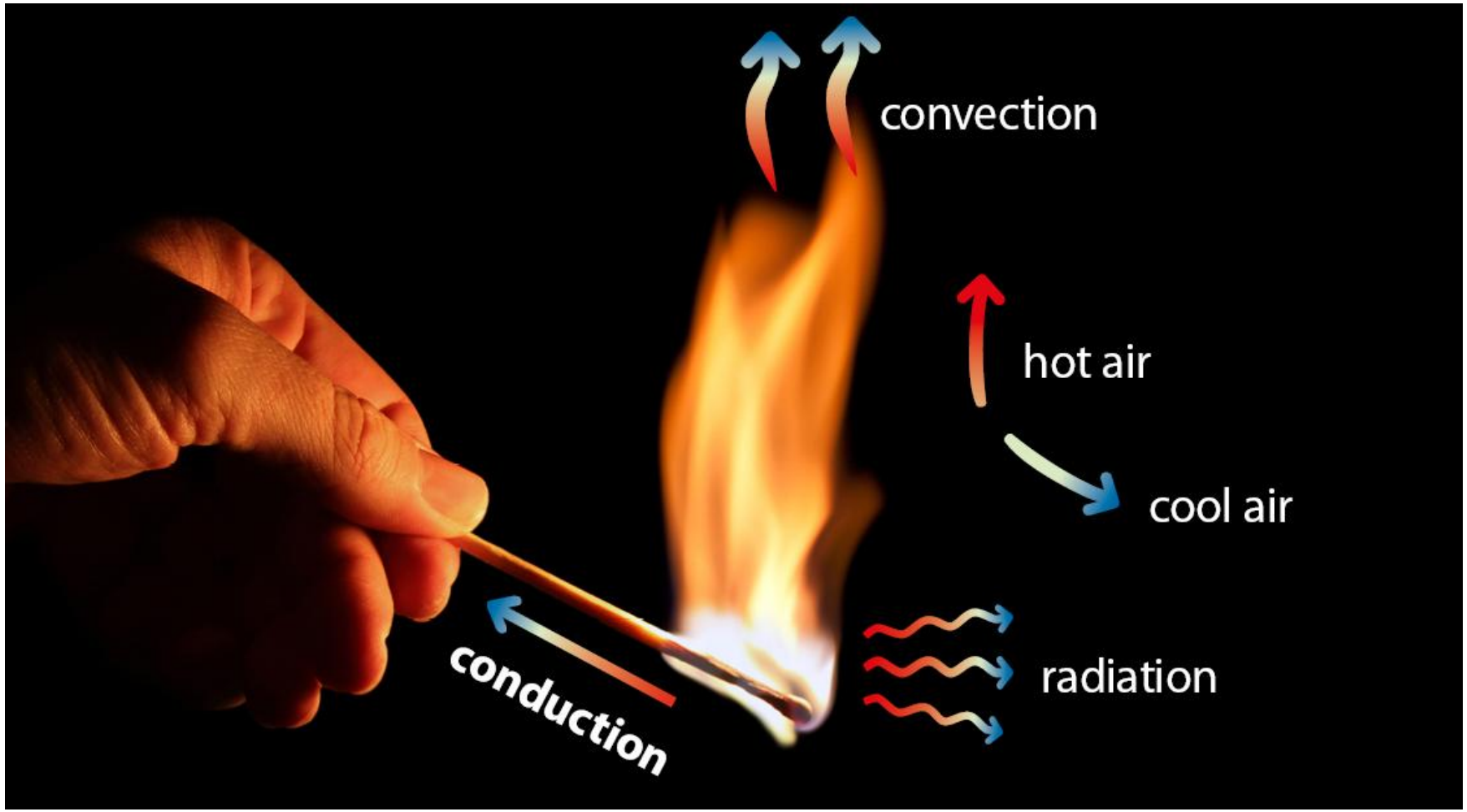
Diffusion

Displacement



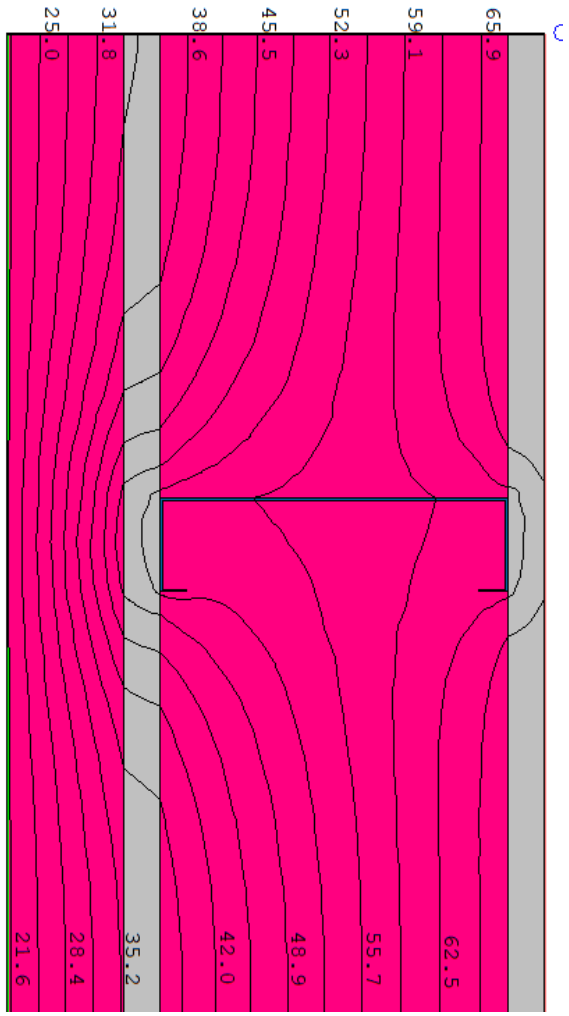
[2] Lstiburek, J. W. (2024). *BSI-149: Slide Rules, Pocket Protectors, Cigarettes and an Iconic Building Science Image*. Building Science Corporation

HEAT TRANSFER



HEAT TRANSFER IN ASSEMBLIES

Exterior
(~20 F)



Interior
(~70 F)

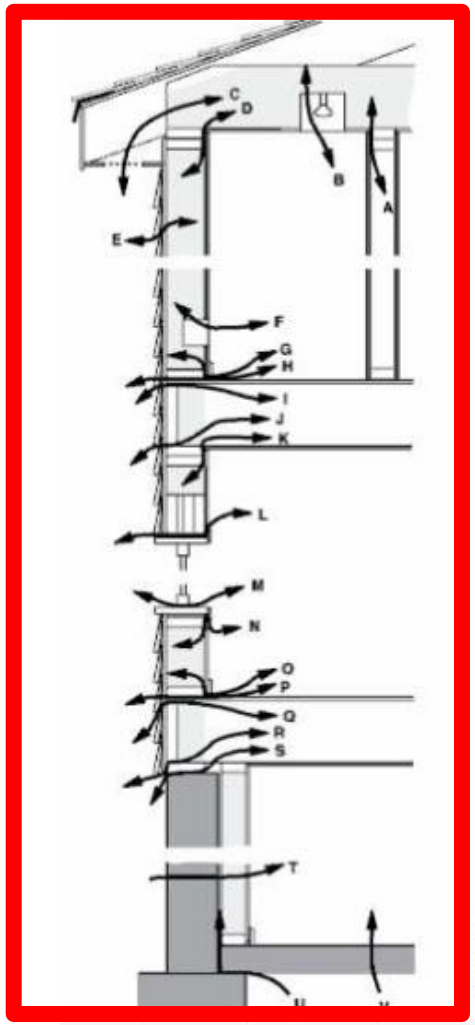
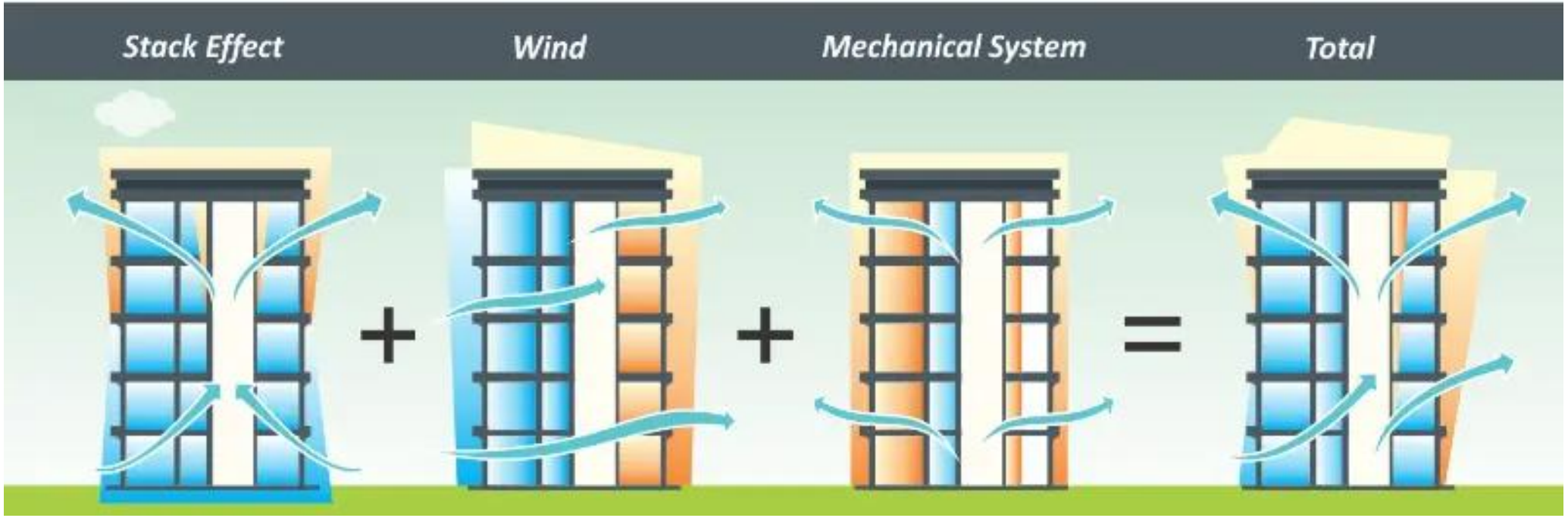


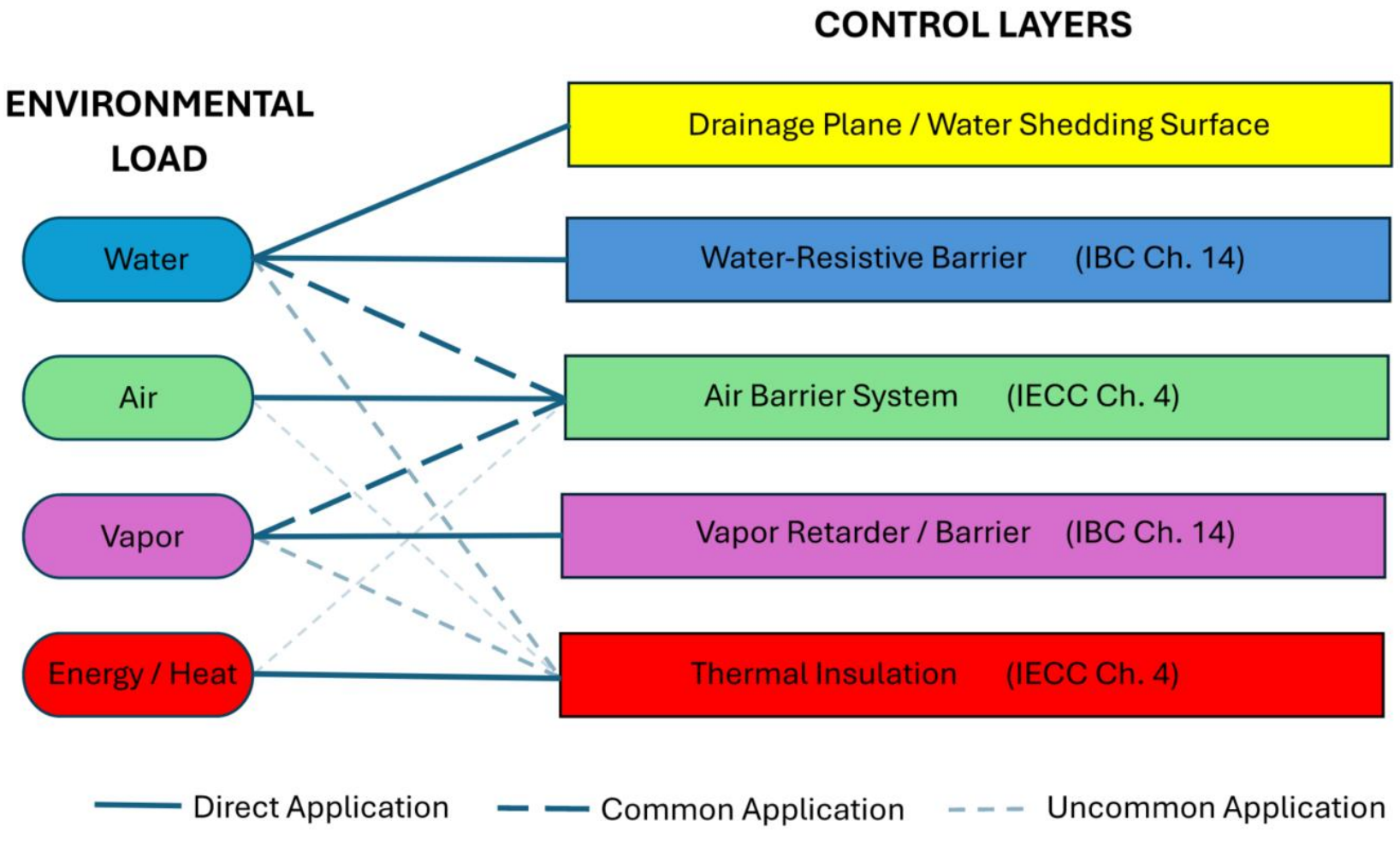
Image from Conservation Technology

DRIVING FORCES

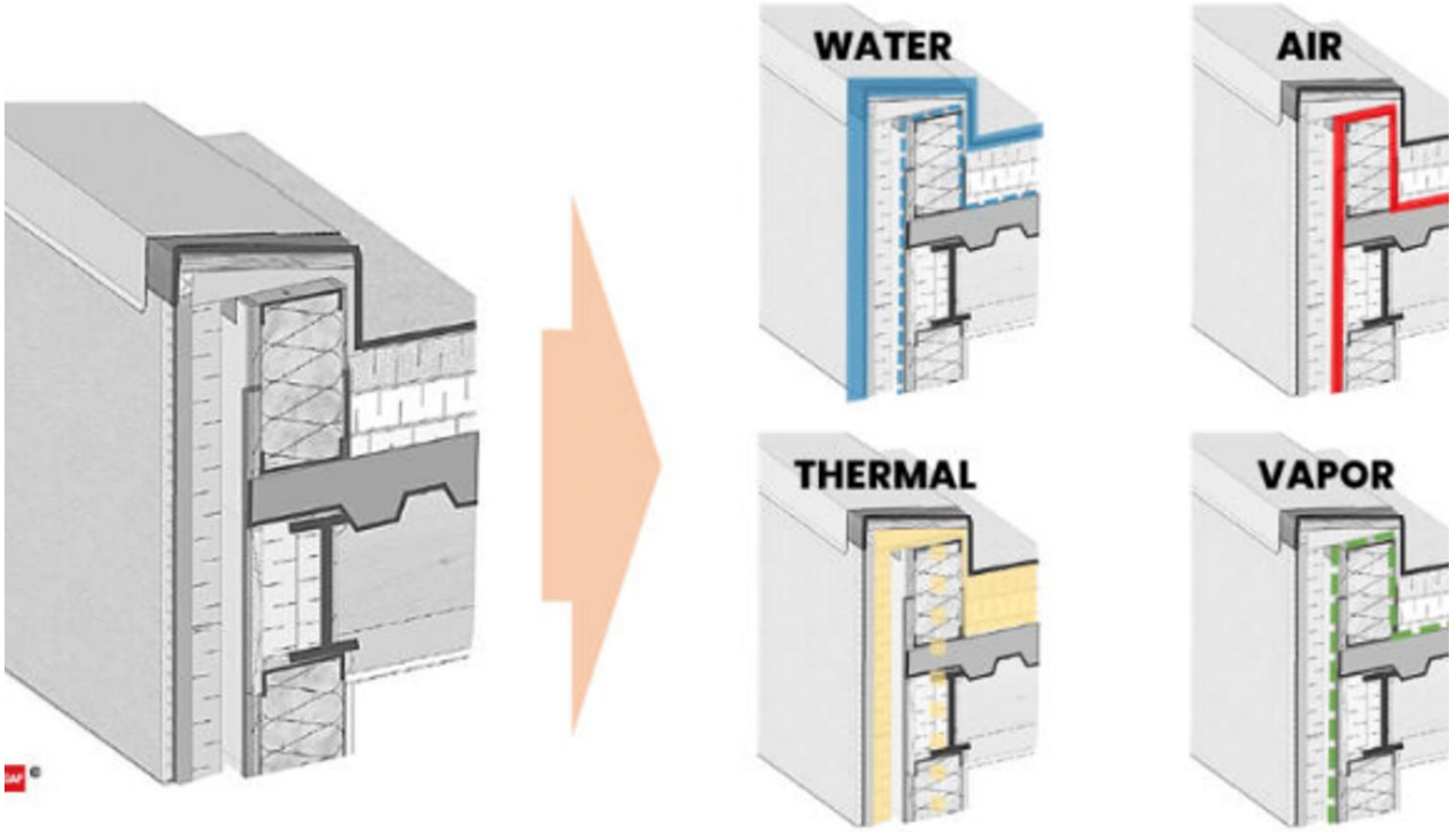
AIR PRESSURE GRADIENT SOURCES



MANAGING ENVIRONMENTAL LOADS



MANAGING ENVIRONMENTAL LOADS



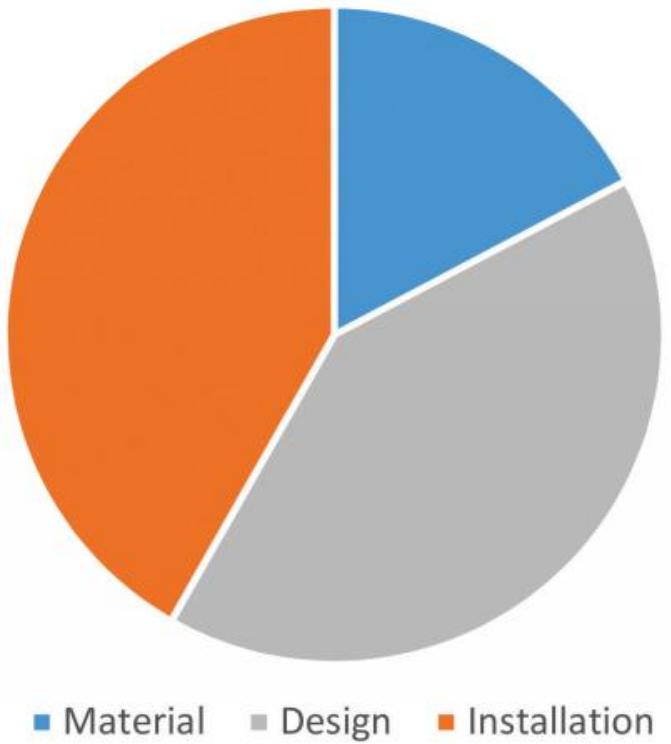
"Parapets – Continuity of Control Layers" Benjamine Meyer, GAF

ENCLOSURE & MECHANICAL

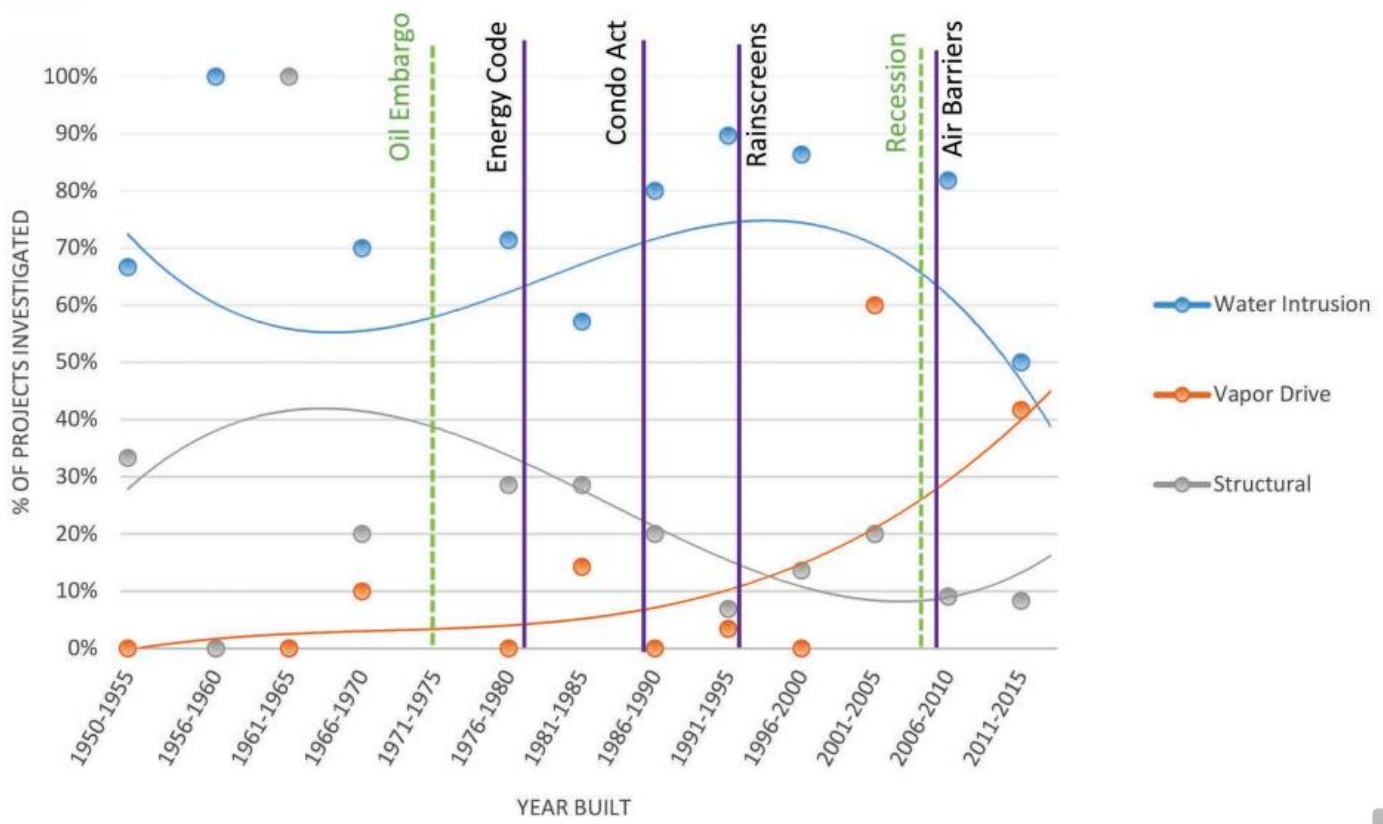
AND / OR

ENCLOSURE FAILURE TRENDS

Failure Causes



Failure Mode



[1] Dunham, L. (2019). *Historical Building Enclosure Performance Through the Lens of Forensic Investigations*. International Institute of Building Enclosure Consultants, Interface Magazine.

ASHRAE 160

Hygrothermal Modeling / Analysis
(WUFI, Moisture-Expert)

- Guidance other than **ASHRAE 160**: *Criteria For Moisture-Control Design Analysis In Buildings* is limited.
  - Criteria for Selecting Analytic Procedures
  - Criteria for Inputs
  - Criteria for Evaluating Outputs
- Does not specifically address human health or comfort
- Hourly time step including
  - Energy Transport (incl. latent effects)
  - Material Properties (function of moisture)
  - Water transport (capillary, deposition, storage, vapor diffusion, water leakage)
  - Ability to Model Ventilated Cavities


STANDARD

ASHRAE

ANSI/ASHRAE Standard 160-2016
(Supersedes ANSI/ASHRAE Standard 160-2009)
Includes ANSI/ASHRAE addenda listed in Annex D

Criteria for Moisture-Control Design Analysis in Buildings

See Annex D for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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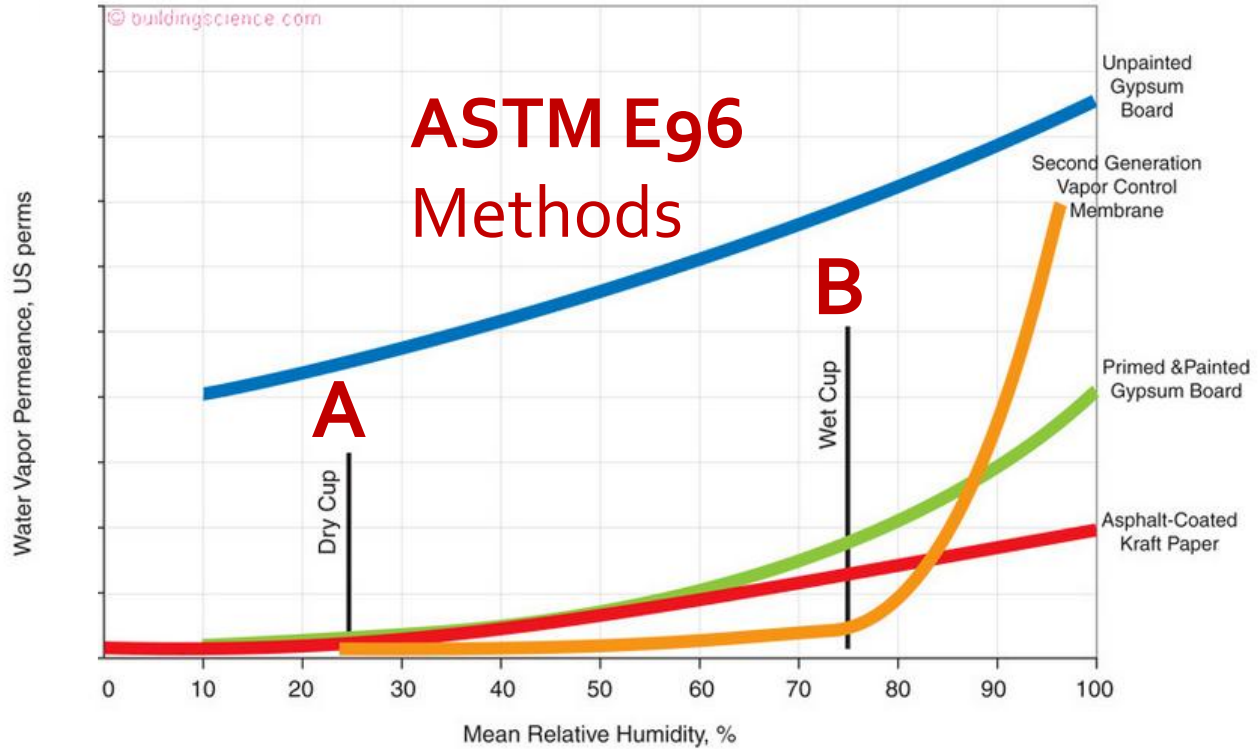
ANSI

TRANSIENT MATERIAL PROPERTIES

Moisture Dependent
(ASHRAE Fundamentals & Mfr. Data)



Temperature Dependent

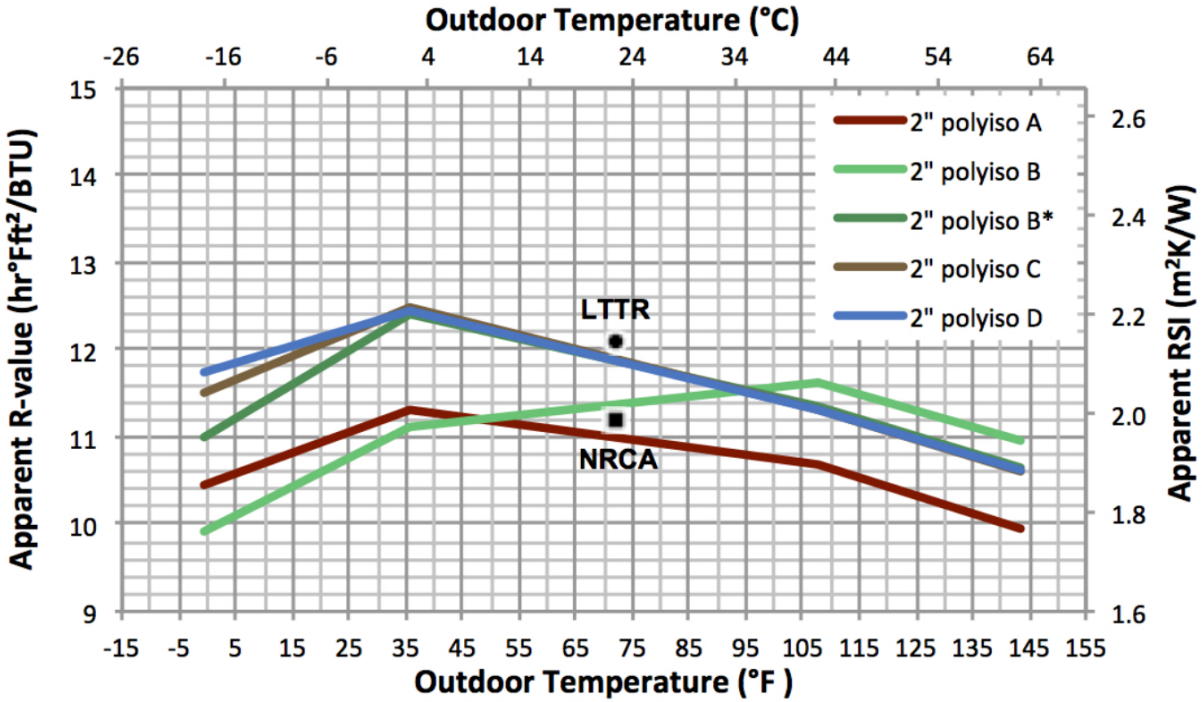


Figure 3: Service temperature R-value test results for nominal R-12.1 (LTTR) / R-11.2 (NRCA) insulation

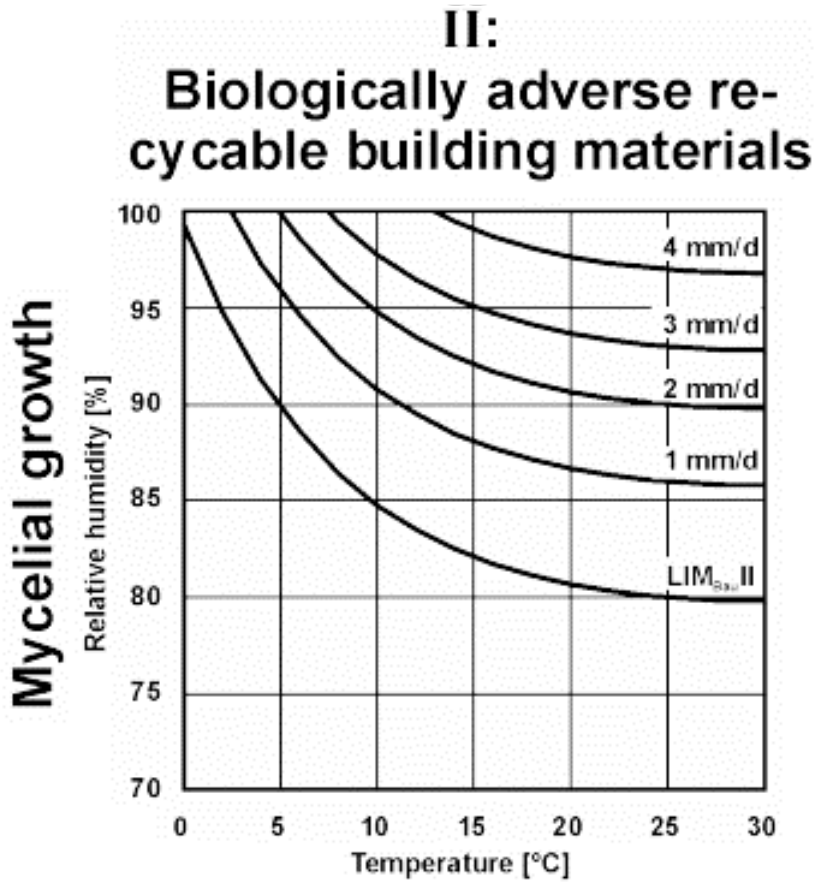
Adapted from:
[6] Lstiburek, J. (2017) Insight – 099: It's All Relative. Building Science Corporation.

[7] (2013) Info-501: Temperature Dependency of R-values in Polyisocyanurate Roof Insulation. Building Science Corporation.

ACCEPTABLE WALL PERFORMANCE

Acceptable wall hygrothermal performance analysis considerations

- Condensation
  - Glaser Method (monthly avgs.): **None**. Below Saturation Vapor Pressure / Dewpoint
  - Transient Model (WUFI): **Dries**
- Mold
  - Dependent on materials (food), temperature, & RH: **<80% RH**
- Corrosion:
  - Dependent on metal
  - 30-day average of hourly surface RH: **<80% RH**

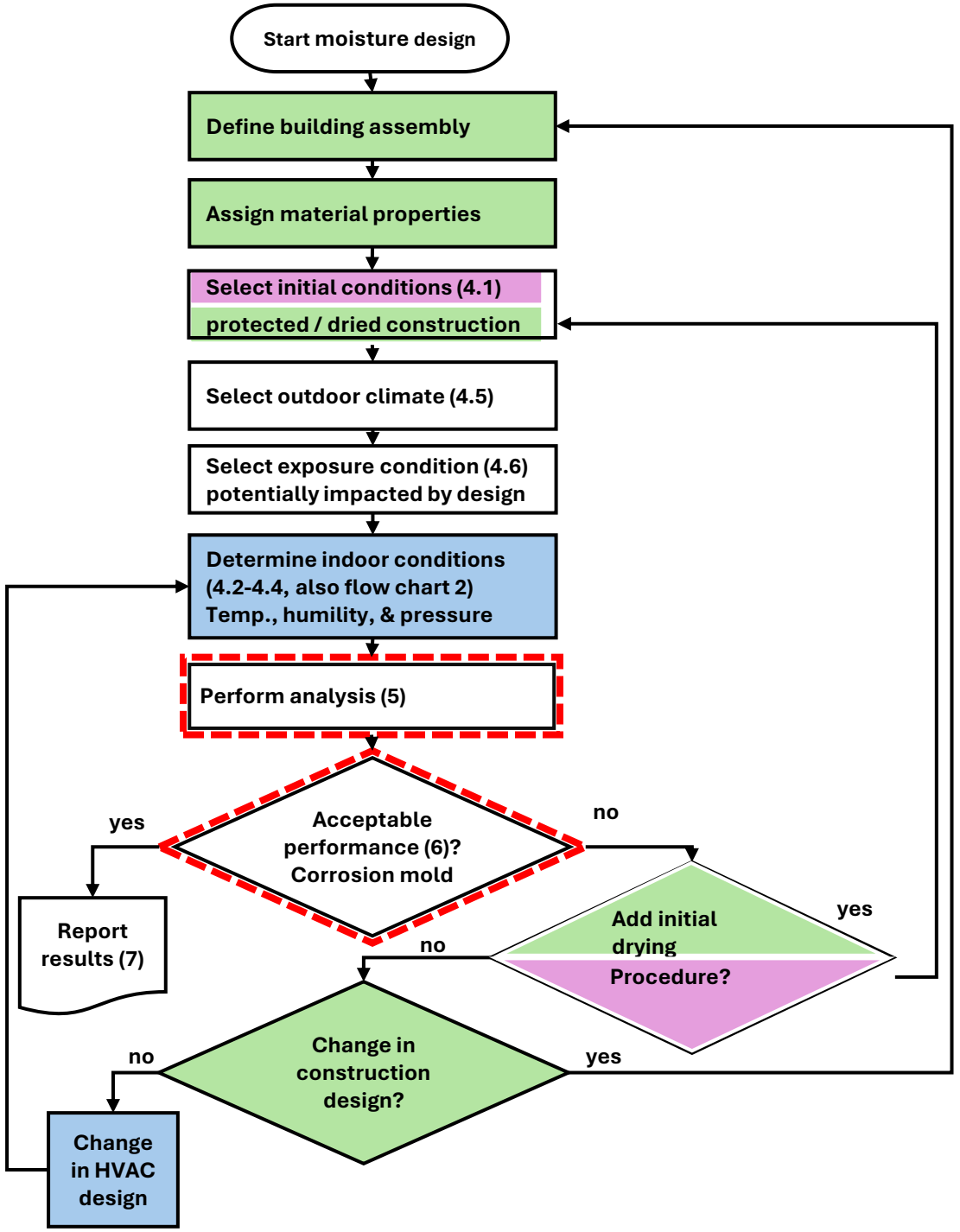


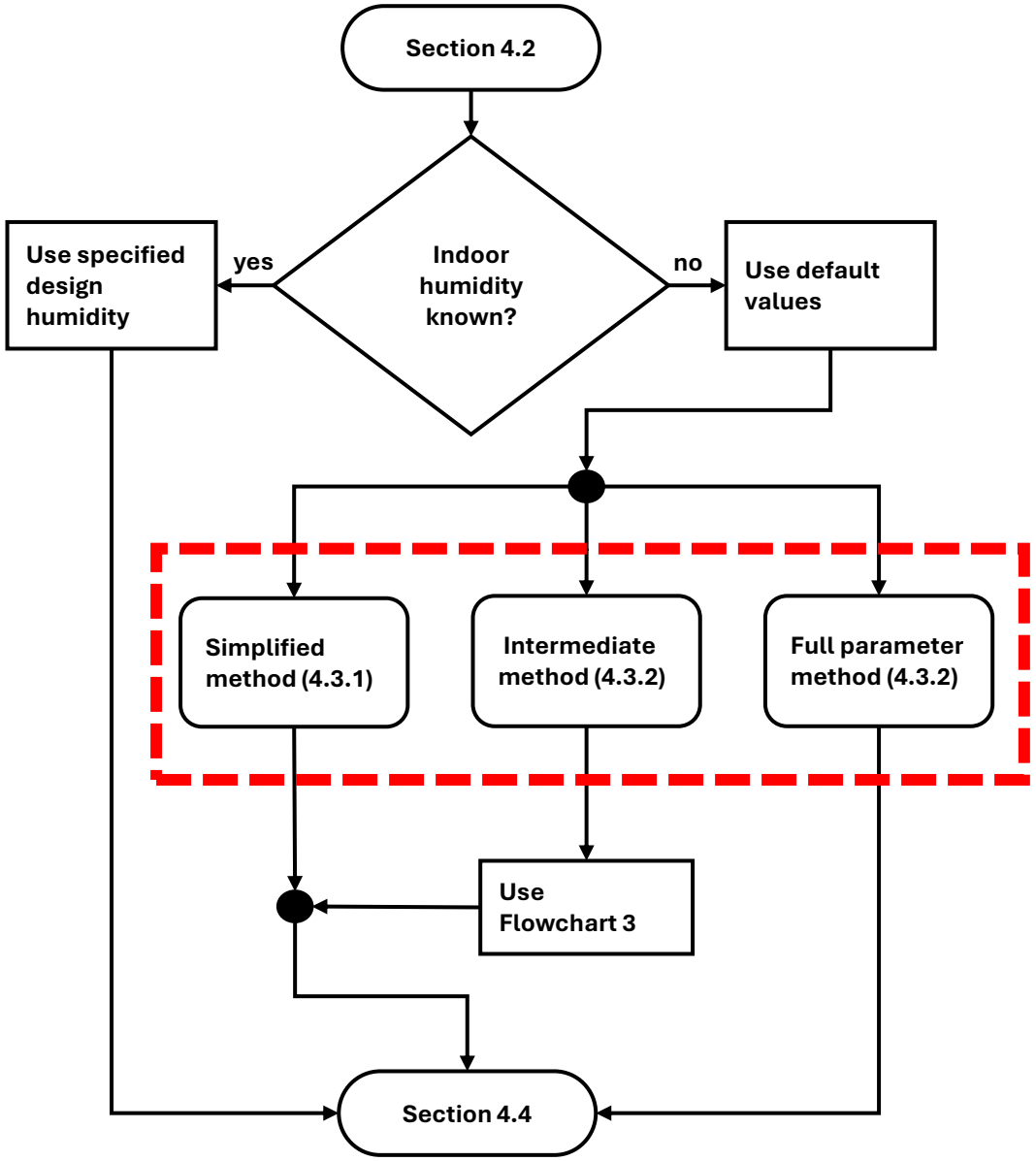
[8] Kurs, M., Sedlbauer, K. (2001) Mold Growth Prediction by Computational Simulation. Fraunhofer Institut Bauphysik.

Architect

Mechanical Engineer

Contractor





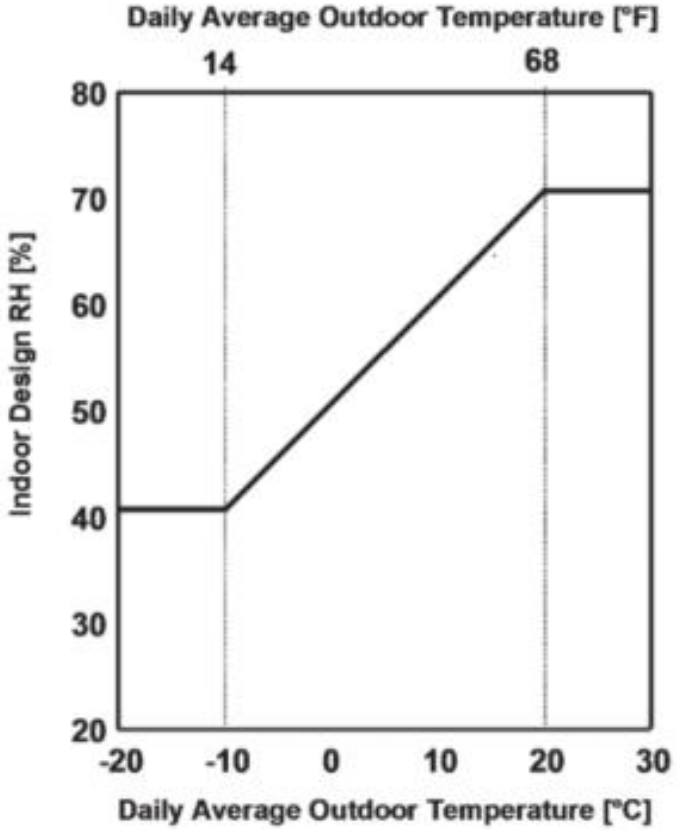
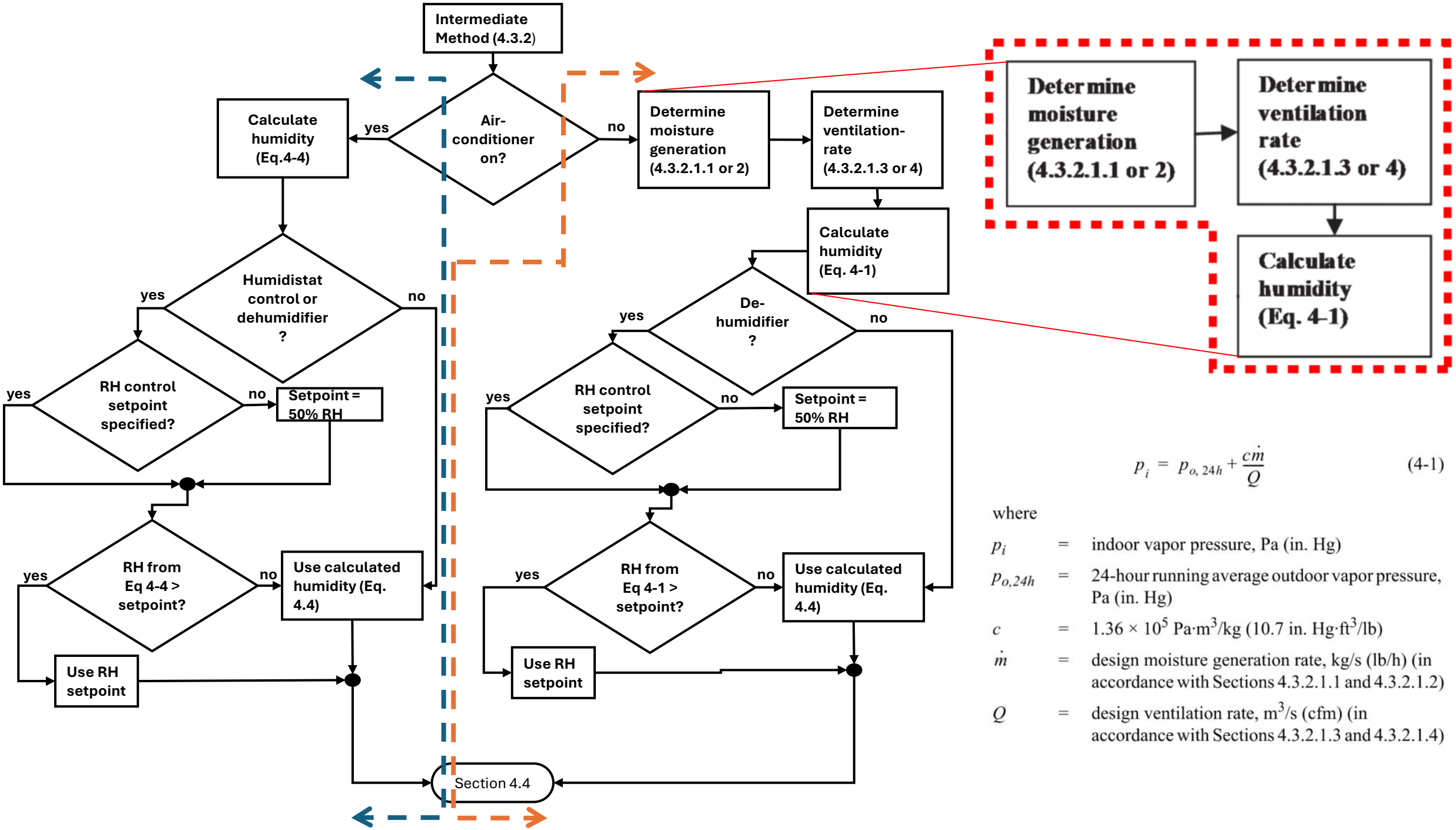


FIGURE 4.3.1 Design indoor relative humidity, simplified method.

4.3.2.1.1 provides guidence on moisture generation for **residential** occupancies.

4.3.2.1.2 indicates in occupancies **other than residential**, moisture generation values "appropriate for the intended use" shall be used & if not available the simplified method shall be used.



$$p_i = p_{o,\,24h} + \frac{c\dot{m}}{Q} \qquad (4\text{-}1)$$

where

p_i = indoor vapor pressure, Pa (in. Hg)

$p_{o,24h}$ = 24-hour running average outdoor vapor pressure, Pa (in. Hg)

c = 1.36×10^5 Pa·m^3/kg (10.7 in. Hg·ft^3/lb)

$\dot{m}$ = design moisture generation rate, kg/s (lb/h) (in accordance with Sections 4.3.2.1.1 and 4.3.2.1.2)

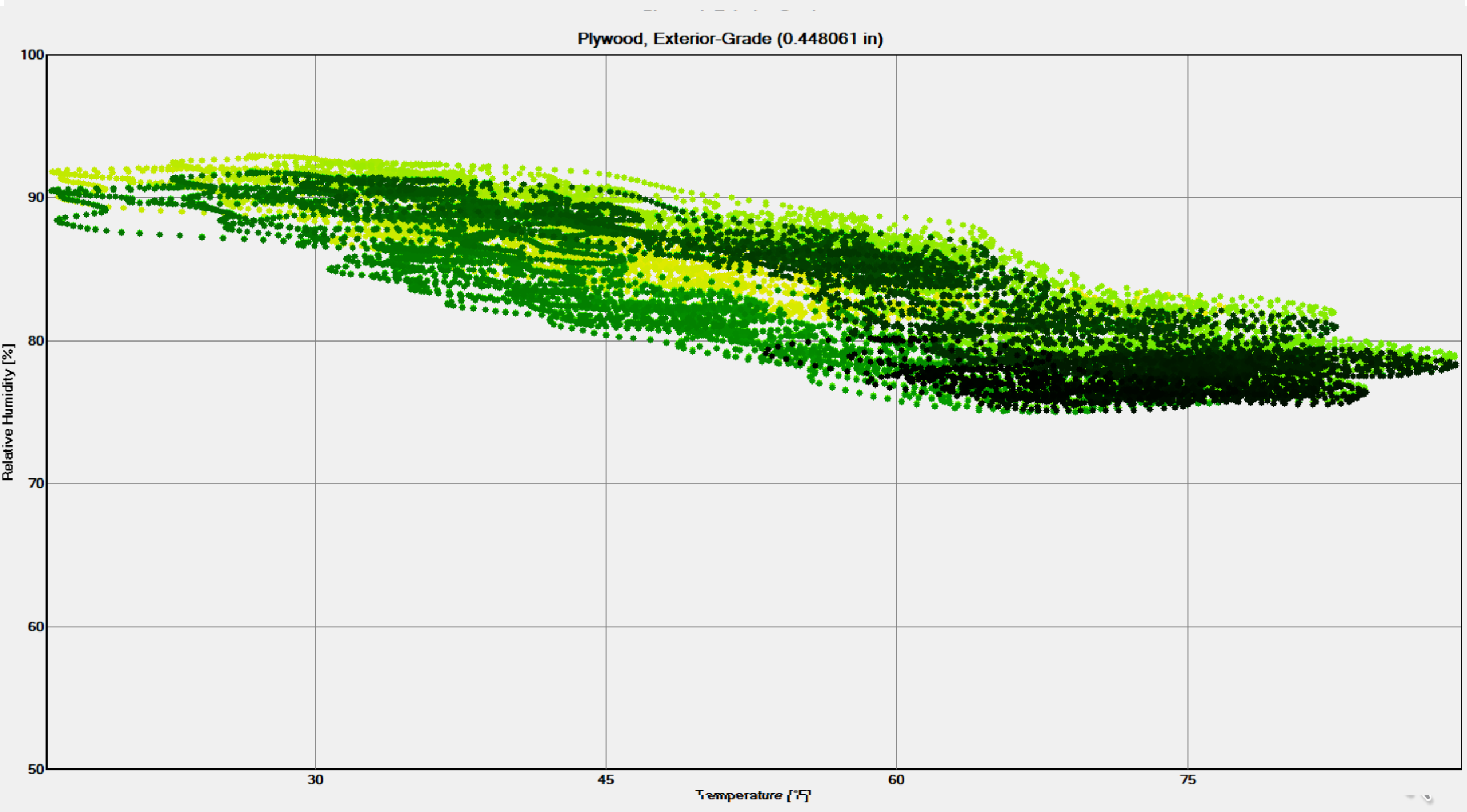
Q = design ventilation rate, m^3/s (cfm) (in accordance with Sections 4.3.2.1.3 and 4.3.2.1.4)

Input requirement of full parametric method.

The analysis shall include thermal and mass balances and shall use simulation algorithms and time-step intervals that capture hygrothermal response of sensitive materials and conditions.

Required inputs include the following:

a. Hygrothermal properties of building materials, finishes, and furniture
b. Design initial moisture conditions (in accordance with Section 4.1)
c. Design indoor temperatures (in accordance with Section 4.2)
d. design ventilation rates (in accordance with Section 4.3.2.1.3 or 4.3.2.1.4)
e. design moisture generation rates (in accordance with Section 4.3.2.1.1 or 4.3.2.1.2)
f. effect of active dehumidification systems
g. design pressure data (in accordance with Section 4.4.1)
h. design weather data (in accordance with Section 4.5)
i. design rain loads (in accordance with Section 4.6)


Plywood, Exterior-Grade (0.448061 in)
100
90
80
70
60
50
Relative Humidity [%]
30
45
60
75
Temperature [°F]

THANK YOU

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