Building Energy Simulation - Parameters

University of Maryland, College Park
Mechanical Engineering Departments
ENME808i / ENME424 – Urban Microclimate and Energy
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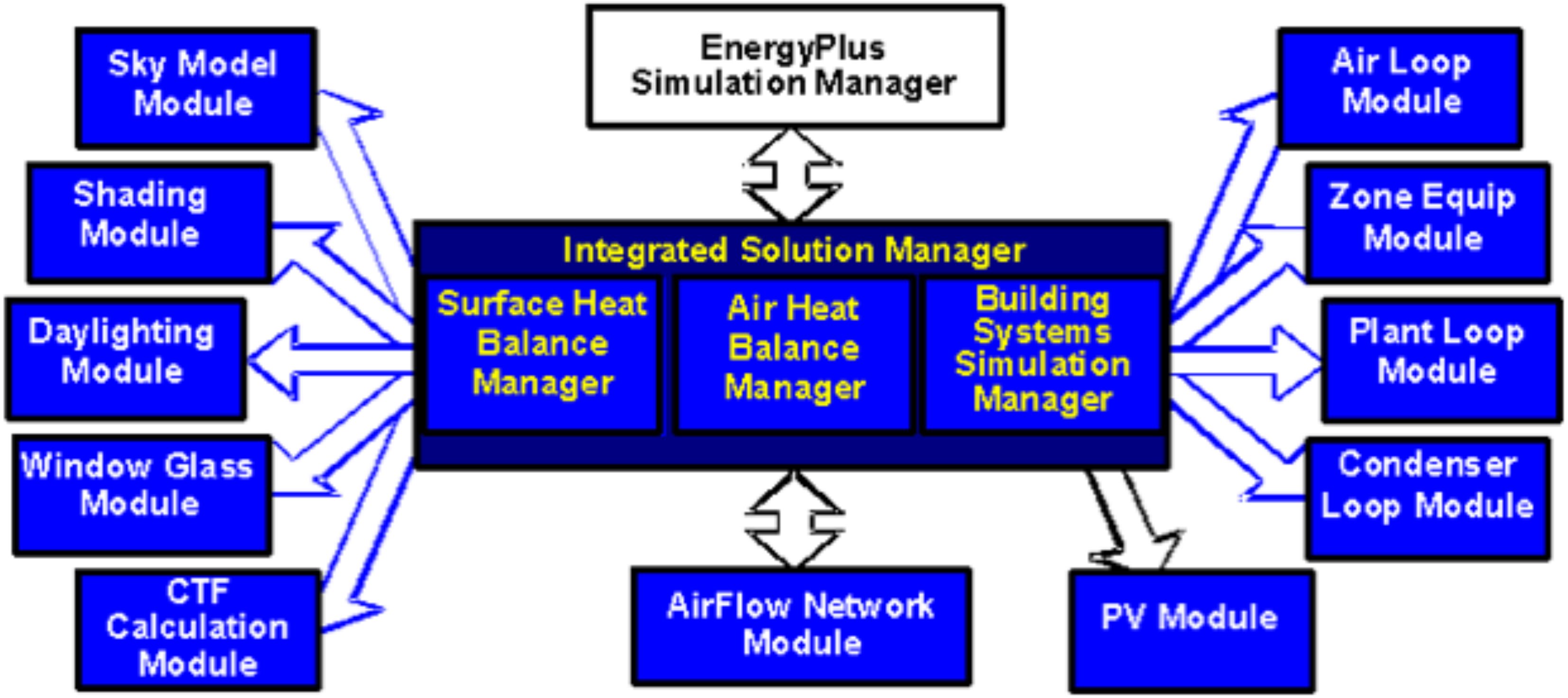
Energy Plus



Visualized!: EnergyPlus Code Flower

EnergyPlus. Engineering Reference. p.28.

Energy Plus Equations – Zone Thermal Balance

$$C_z \frac{dT_z}{dt} = \sum_{i=1}^{N_{sl}} \dot{Q}_i + \sum_{i=1}^{N_{surfaces}} h_i A_i \left(T_{si} - T_z\right) + \sum_{i=1}^{N_{zones}} \dot{m}_i C_p \left(T_{zi} - T_z\right) + \dot{m}_{\inf} C_p \left(T_\infty - T_z\right) + \dot{Q}_{sys}$$

$\sum_{i=1}^{N_{sl}} \dot{Q}_i$ = sum of the convective internal loads

$\sum_{i=1}^{N_{surfaces}} h_i A_i \left(T_{zi} - T_z\right)$ = convective heat transfer from the zone surfaces

$\dot{m}_{\inf} C_p \left(T_\infty - T_z\right)$ = heat transfer due to infiltration of outside air

$\sum_{i=1}^{N_{zones}} \dot{m}_i C_p \left(T_{zi} - T_z\right)$ = heat transfer due to interzone air mixing

$\dot{Q}_{sys}$ = air systems output

$C_z \frac{dT_z}{dt}$ = energy stored in zone air

$C_z = \rho_{air} C_p C_T$

ρ_{air} = zone air density

C_p = zone air specific heat

C_T = sensible heat capacity multiplier

EnergyPlus Engineering Reference.
Integrated Solution Manager. p 7.

Weather Data

- Typical Meteorological Year (TMY3)
  - 30 yrs (1976-2005), ~2,000 sites available (~1,000 U.S.)
  - For a month, determine typical global horizontal radiation, direct normal radiation, dry bulb temperature, dew point temperature, and wind speed.
  - Month with most typical values is used to construct 12 month
  - Available here
- Annual Meteorological Year (AMY)
  - Actual weather data for a given year

Geometry

- Model building as a single shape
- Model as single thermal zone (for now)
- Fix a uniform window-to-wall ratio (0.15-0.25)
- Set building orientation

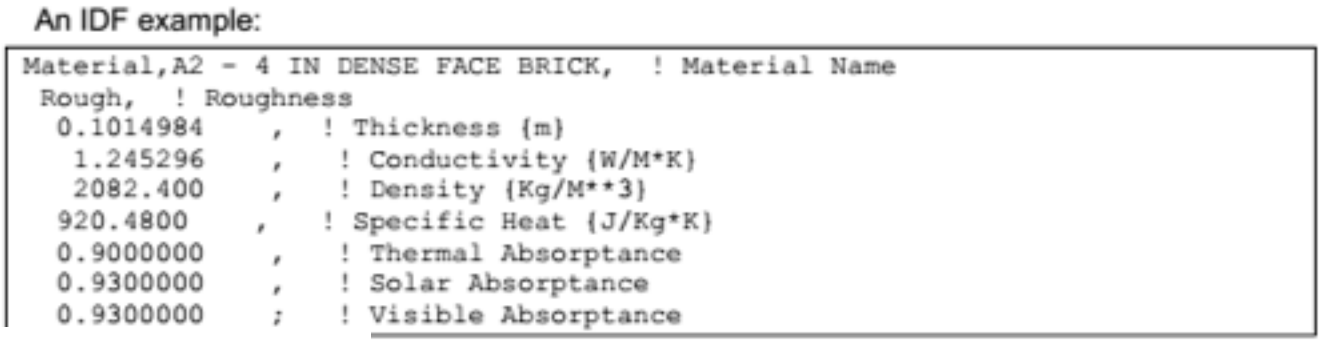
Construction

- Two types of surfaces:
  - Exterior (heat transfer)
  - Interior surfaces (thermal storage)

- Constructions are composed of layers of materials

- Surfaces with same orientation/properties are lumped into one surface for a thermal zone
  - e.g. combine windows facing same direction

Construction



An IDF example:

```
Material,A2 - 4 IN DENSE FACE BRICK,   ! Material Name
 Rough,   ! Roughness
  0.1014984     ,   ! Thickness {m}
   1.245296     ,    ! Conductivity {W/M*K}
   2082.400     ,    ! Density {Kg/M**3}
  920.4800     ,    ! Specific Heat {J/Kg*K}
  0.9000000     ,    ! Thermal Absorptance
  0.9300000     ,    ! Solar Absorptance
  0.9300000     ;    ! Visible Absorptance
```

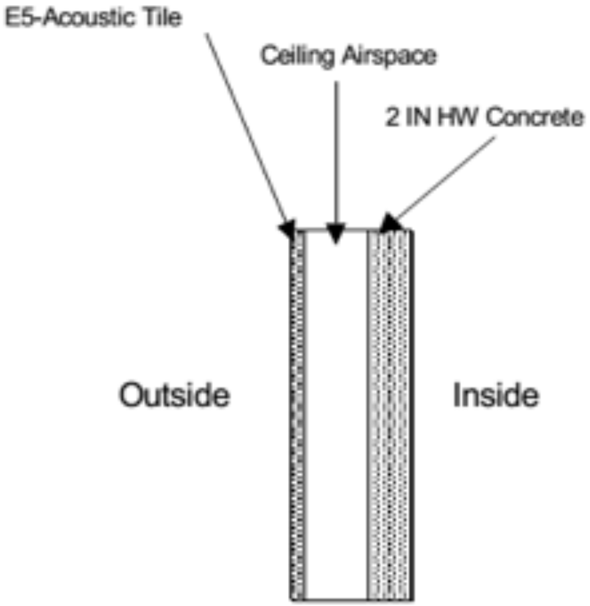
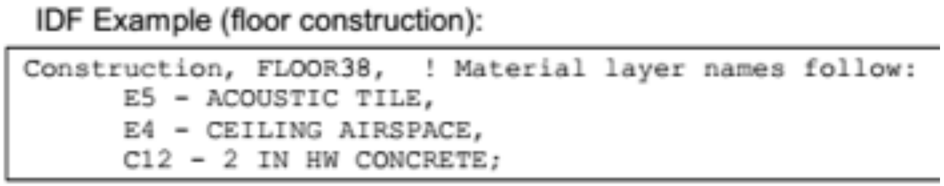


Figure 22. Example Floor Construction illustration.

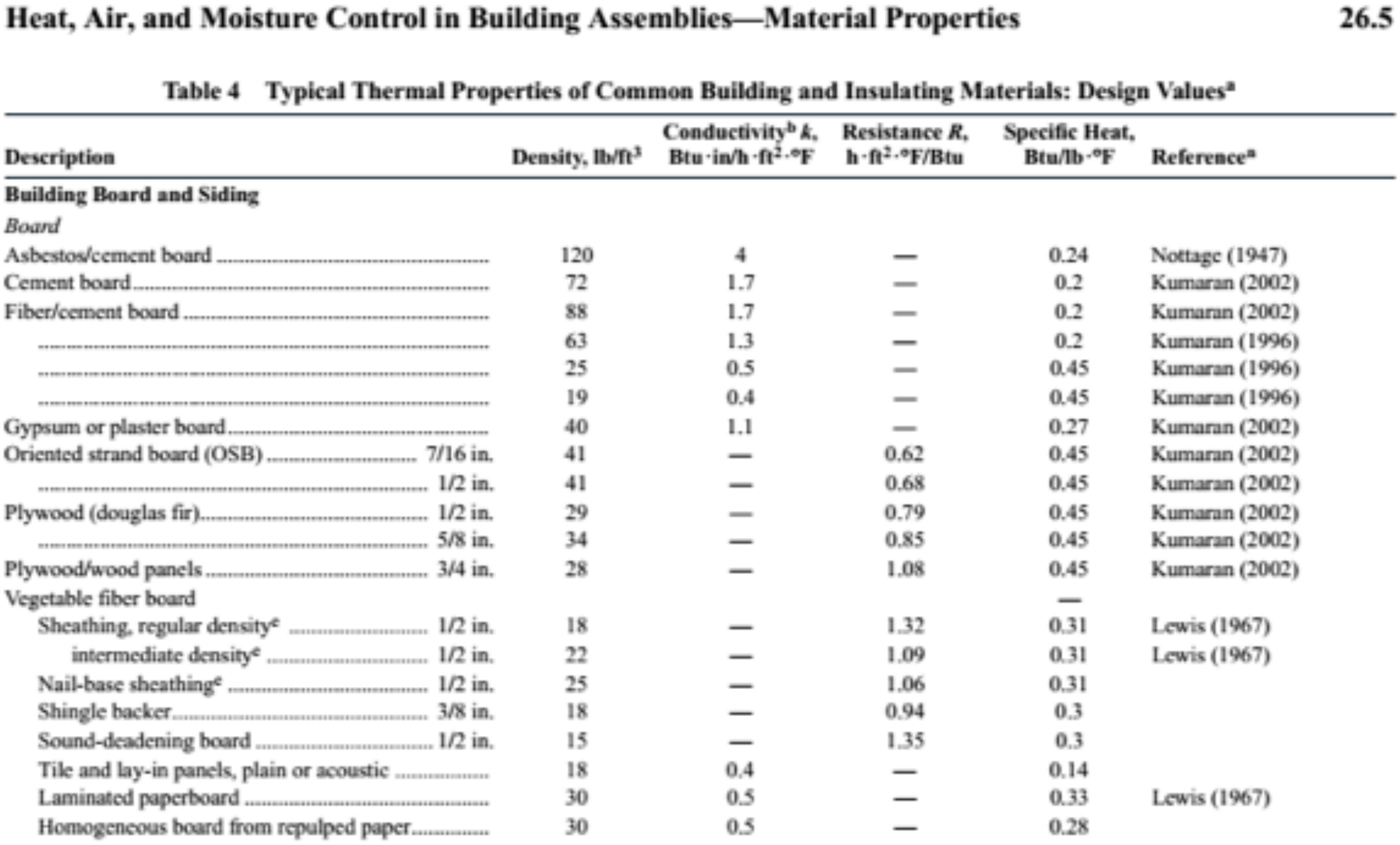


IDF Example (floor construction):

```
Construction, FLOOR38,   ! Material layer names follow:
      E5 - ACOUSTIC TILE,
      E4 - CEILING AIRSPACE,
      C12 - 2 IN HW CONCRETE;
```

EnergyPlus. Input/Output Reference. p.151.

Construction



Heat, Air, and Moisture Control in Building Assemblies—Material Properties **26.5**

Table 4 Typical Thermal Properties of Common Building and Insulating Materials: Design Values[a]

Description	Density, lb/ft³	Conductivity[b] k, Btu·in/h·ft²·°F	Resistance R, h·ft²·°F/Btu	Specific Heat, Btu/lb·°F	Reference[a]
Building Board and Siding					
Board					
Asbestos/cement board	120	4	—	0.24	Nottage (1947)
Cement board	72	1.7	—	0.2	Kumaran (2002)
Fiber/cement board	88	1.7	—	0.2	Kumaran (2002)
	63	1.3	—	0.2	Kumaran (1996)
	25	0.5	—	0.45	Kumaran (1996)
	19	0.4	—	0.45	Kumaran (1996)
Gypsum or plaster board	40	1.1	—	0.27	Kumaran (2002)
Oriented strand board (OSB) 7/16 in.	41	—	0.62	0.45	Kumaran (2002)
1/2 in.	41	—	0.68	0.45	Kumaran (2002)
Plywood (douglas fir) 1/2 in.	29	—	0.79	0.45	Kumaran (2002)
5/8 in.	34	—	0.85	0.45	Kumaran (2002)
Plywood/wood panels 3/4 in.	28	—	1.08	0.45	Kumaran (2002)
Vegetable fiber board				—	
Sheathing, regular density[c] 1/2 in.	18	—	1.32	0.31	Lewis (1967)
intermediate density[c] 1/2 in.	22	—	1.09	0.31	Lewis (1967)
Nail-base sheathing[c] 1/2 in.	25	—	1.06	0.31	
Shingle backer 3/8 in.	18	—	0.94	0.3	
Sound-deadening board 1/2 in.	15	—	1.35	0.3	
Tile and lay-in panels, plain or acoustic	18	0.4	—	0.14	
Laminated paperboard	30	0.5	—	0.33	Lewis (1967)
Homogeneous board from repulped paper	30	0.5	—	0.28	

ASHRAE HOF 2009 – Chp. 26.5 Material Properties

Infiltration

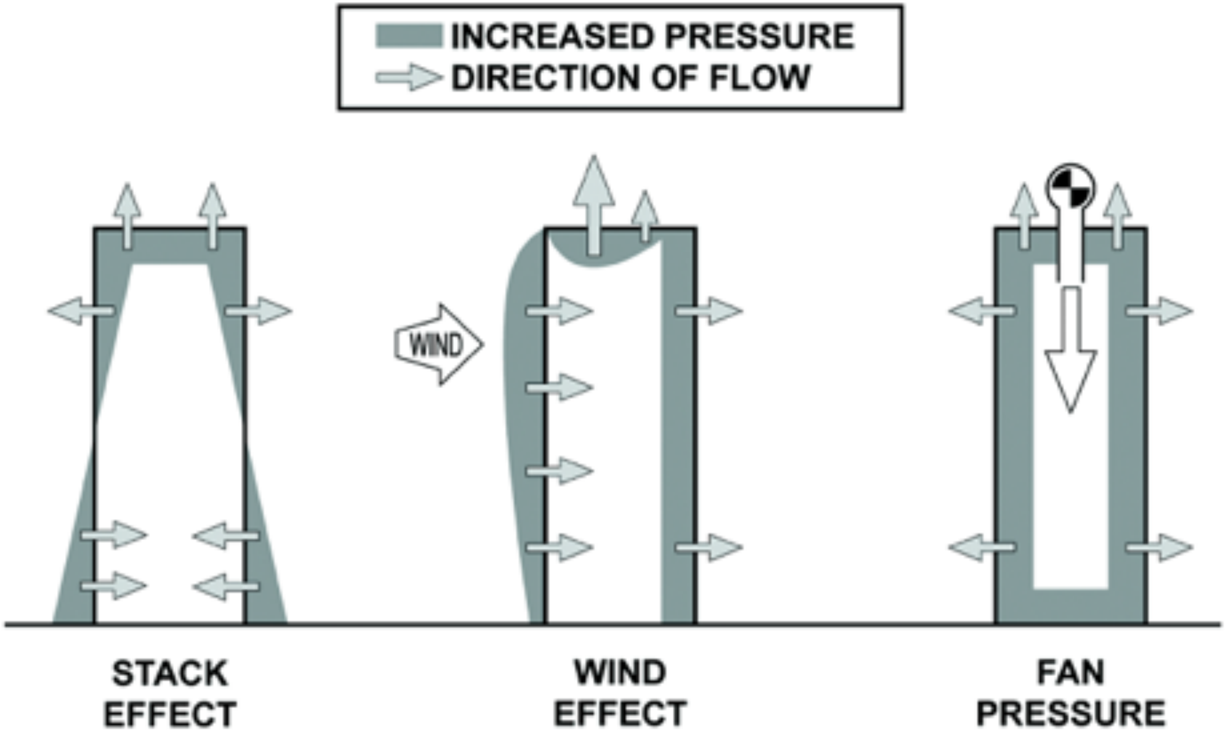


Figure 1 *Forces affecting air leakage.*

T. Woods. Improving the Building Envelope to Meet the Challenges of New Research and Regulation. ASHRAE 2007

Infiltration

Three ways to calculate infiltration:

Design Flow Rate

$$Infiltration = (I_{design})(F_{schedule})\left[A + B\left|(T_{zone} - T_{odb})\right| + C(WindSpeed) + D(Windspeed^2)\right]$$

Effective Leakage Area

$$Infiltration = (F_{Schedule})\frac{A_L}{1000}\sqrt{C_s \Delta T + C_w (WindSpeed)^2}$$

Flow Coefficient

$$Infiltration = (F_{Schedule})\sqrt{(c C_s \Delta T^n)^2 + (c C_w (s * WindSpeed)^{2n})^2}$$

EnergyPlus Engineering Reference. Infiltration/Ventilation. p 343.

Infiltration

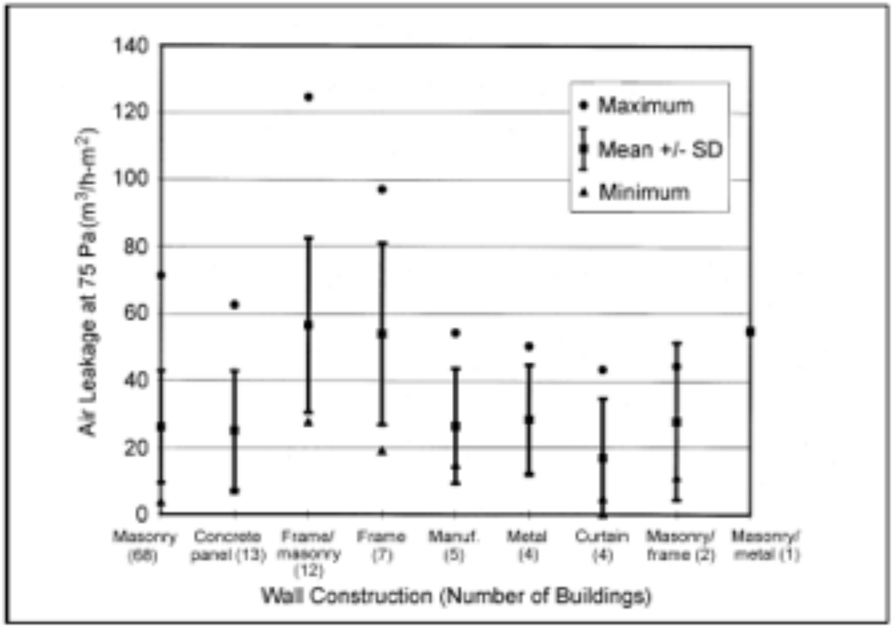


Figure 3: Airtightness values grouped by wall construction.

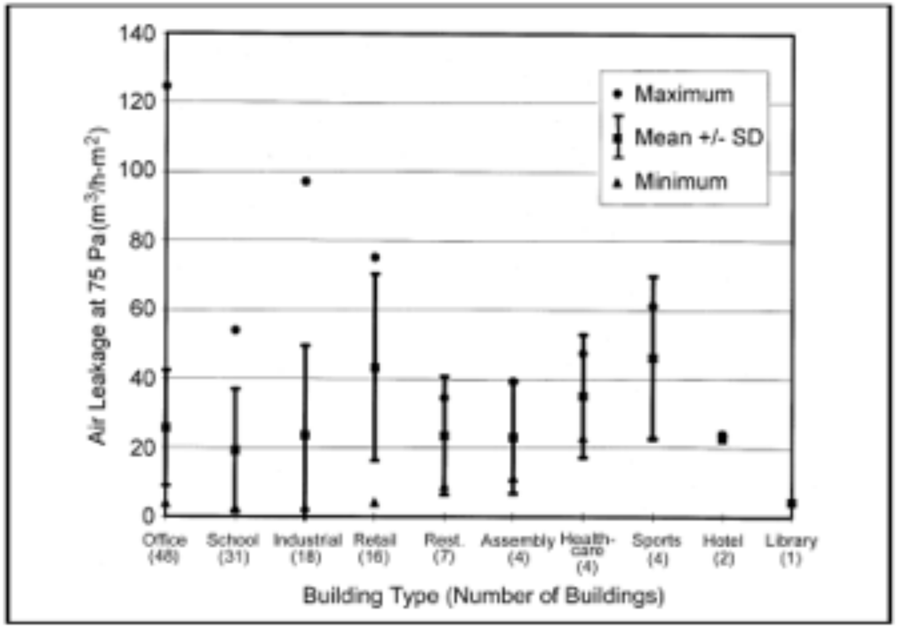


Figure 4: Airtightness values grouped by building type.

A. Persily. Myths About Building Envelopes. ASHRAE J 1999

Infiltration

- Current research is integrating multi-zone air flow tools (CONTAM) with EnergyPlus for directional, dynamic infiltration

  (still using default assumptions for leakiness)

- Use constant 25 $m^3/h\text{-}m^2$ at 75 Pa for now. Convert to other pressures by the relation:

$$Q = C(\Delta P)^n, \; n \approx 0.65$$

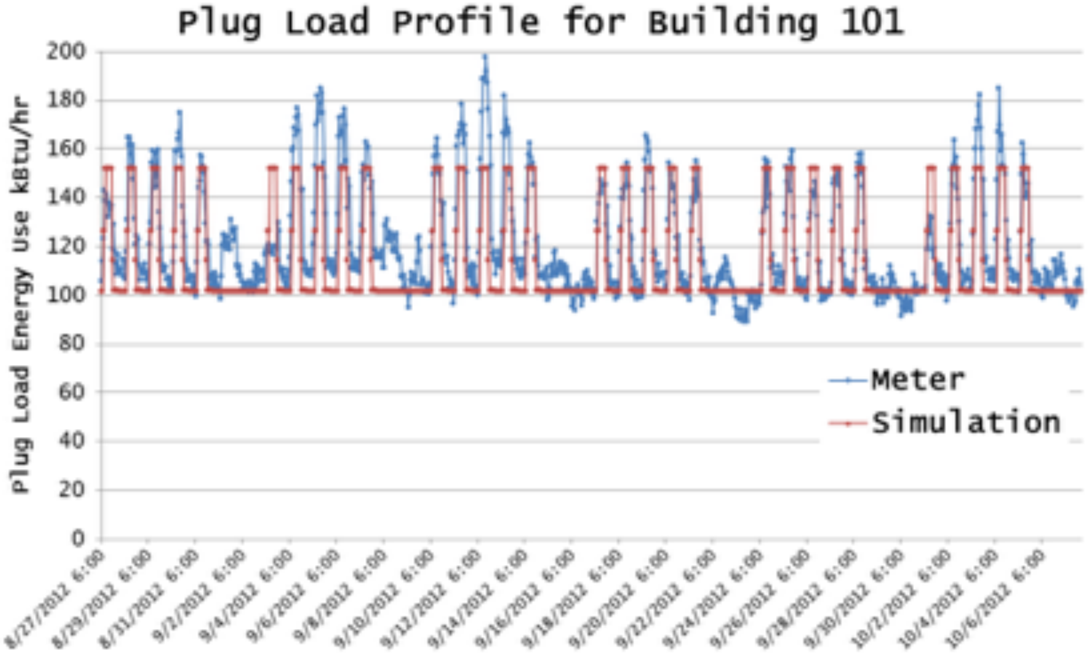
See ASHRAE HOF Chp.16 Ventilation and Infiltration

Space Type Templates

- Plug Load Density, Schedule
- Occupancy Density, Schedule, Metabolic Rate
- Domestic Hot Water Rate, Schedule
- Lighting Level
- Temperature/Humidity Control, Schedule
- Ventilation

Plug Load

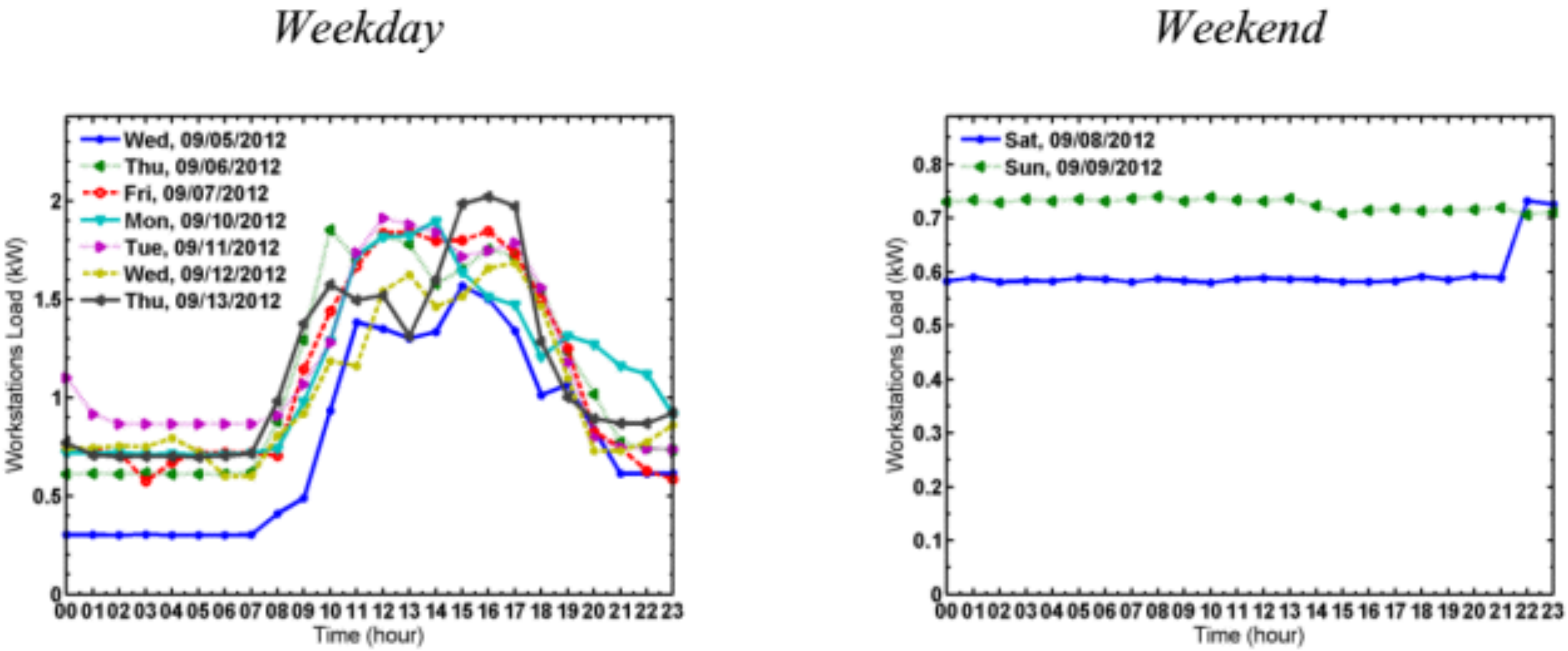
- 25-35% of energy use in newer buildings[1]
- Modeled as W/ft^2 + diversity factor schedule
- Can determine range from electric <15 min interval data



[1] Mohammad Heidarinejad, Matthew Dahlhausen, Sean McMahon, Chris Pyke, Jelena Srebric, Cluster analysis of simulated energy use for LEED certified U.S. office buildings, Energy and Buildings, Volume 85, December 2014, Pages 86-97

[2] Building 101 data from EEB Hub (2013)

Plug Load



Weekday

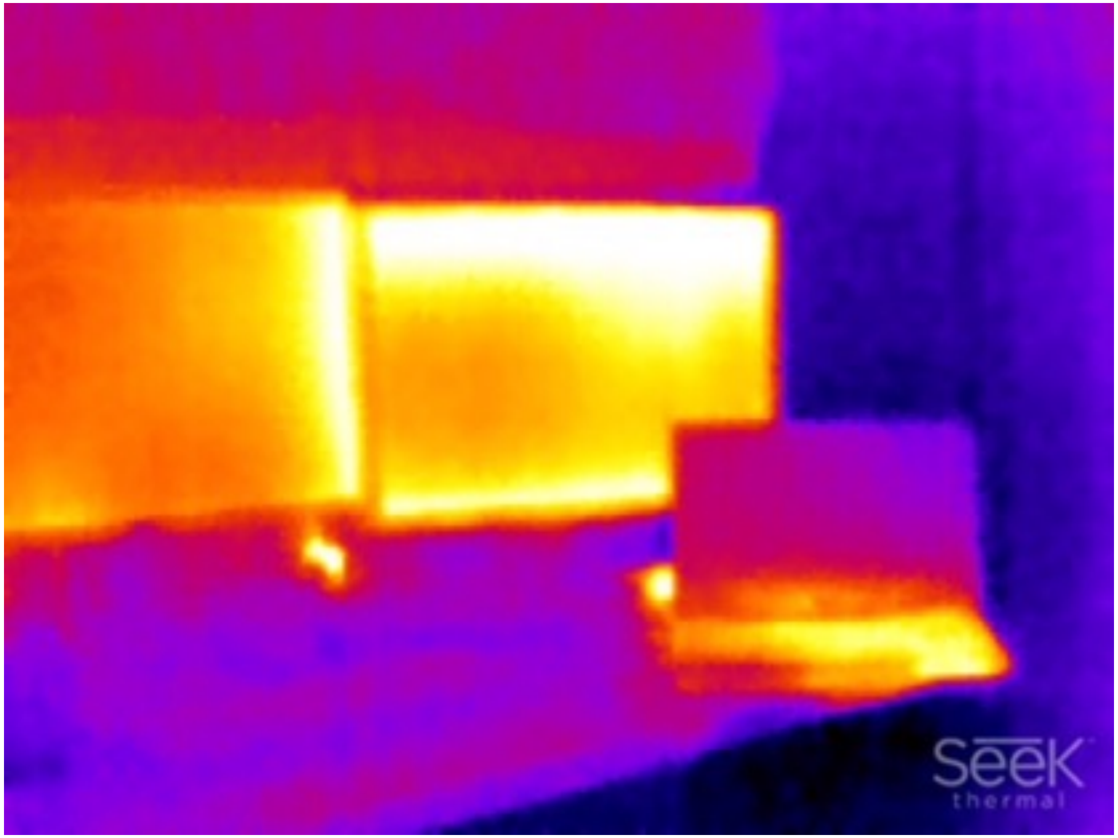
Weekend

Figure 4. Plug load profiles for workstations.

Delogoshaei et al. (2013) Hourly plug load measurements... AEI 2013

Plug Load

$f_{convected}$ = 1.0 – (Fraction Latent + Fraction Radiant + Fraction Lost)



Use default:

- fraction radiant = 0.2
- fraction latent = 0
- fraction lost = 0

EnergyPlus. Input/Output Reference. p.366.

Lighting

Lighting: #1 primary energy end user in commercial buildings (20% of energy use).

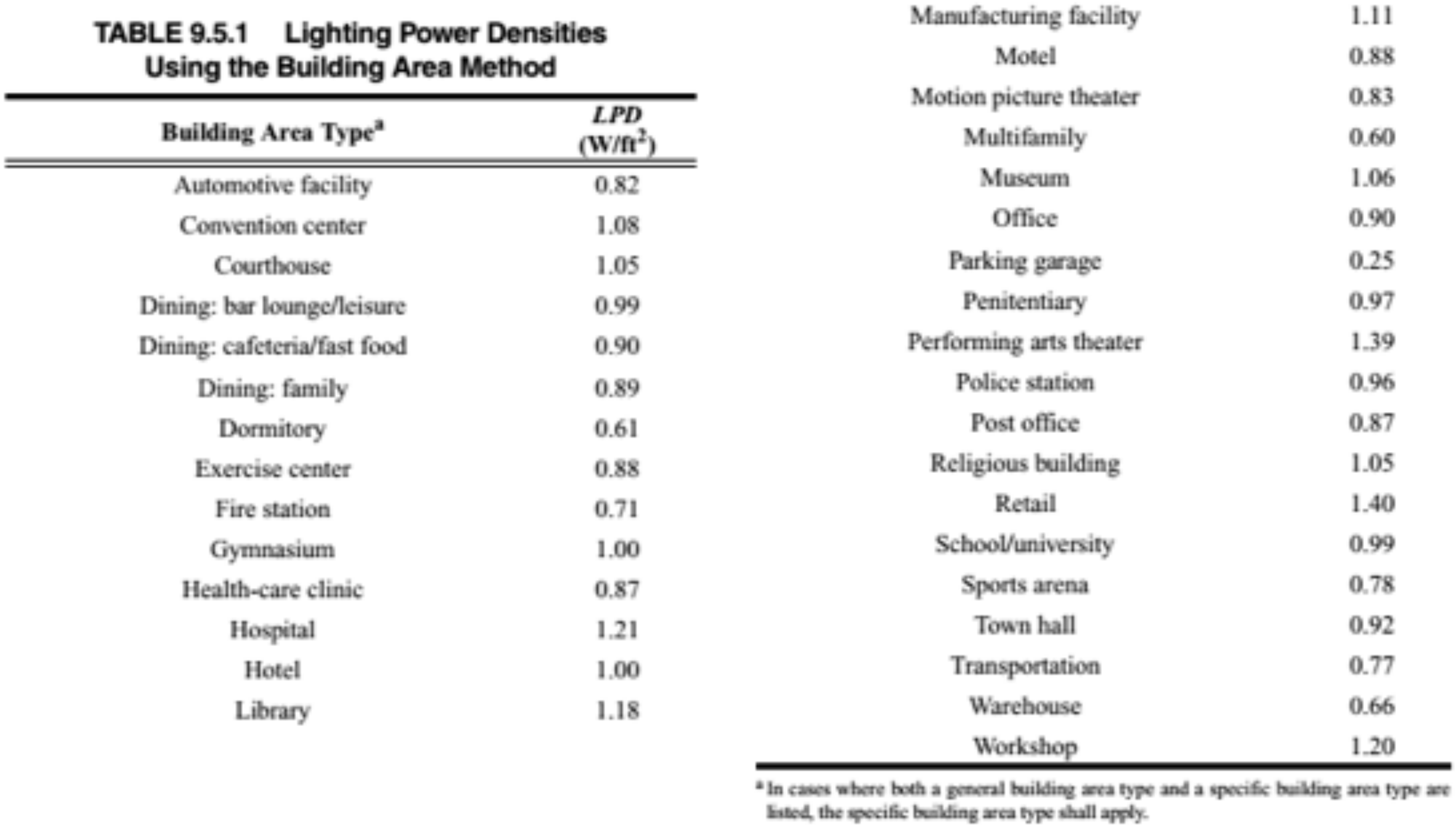


TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

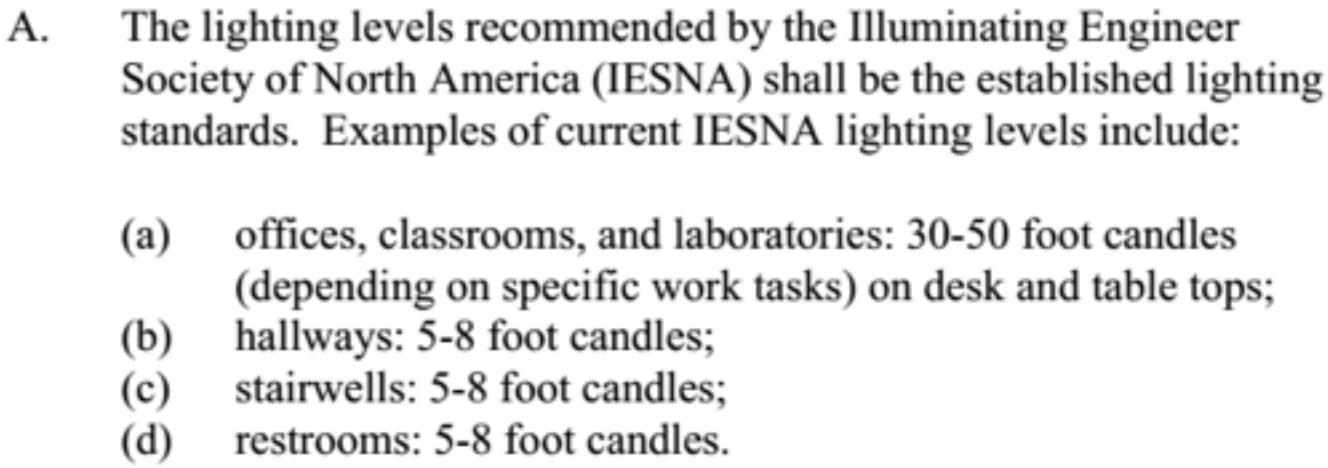
Building Area Type[a]	*LPD* (W/ft^2)
Automotive facility	0.82
Convention center	1.08
Courthouse	1.05
Dining: bar lounge/leisure	0.99
Dining: cafeteria/fast food	0.90
Dining: family	0.89
Dormitory	0.61
Exercise center	0.88
Fire station	0.71
Gymnasium	1.00
Health-care clinic	0.87
Hospital	1.21
Hotel	1.00
Library	1.18
Manufacturing facility	1.11
Motel	0.88
Motion picture theater	0.83
Multifamily	0.60
Museum	1.06
Office	0.90
Parking garage	0.25
Penitentiary	0.97
Performing arts theater	1.39
Police station	0.96
Post office	0.87
Religious building	1.05
Retail	1.40
School/university	0.99
Sports arena	0.78
Town hall	0.92
Transportation	0.77
Warehouse	0.66
Workshop	1.20

[a] In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

ASHRAE Standard 90.1 – 2010. Chp.9 – Lighting.

Lighting

UMD Policy X-13.00(A)



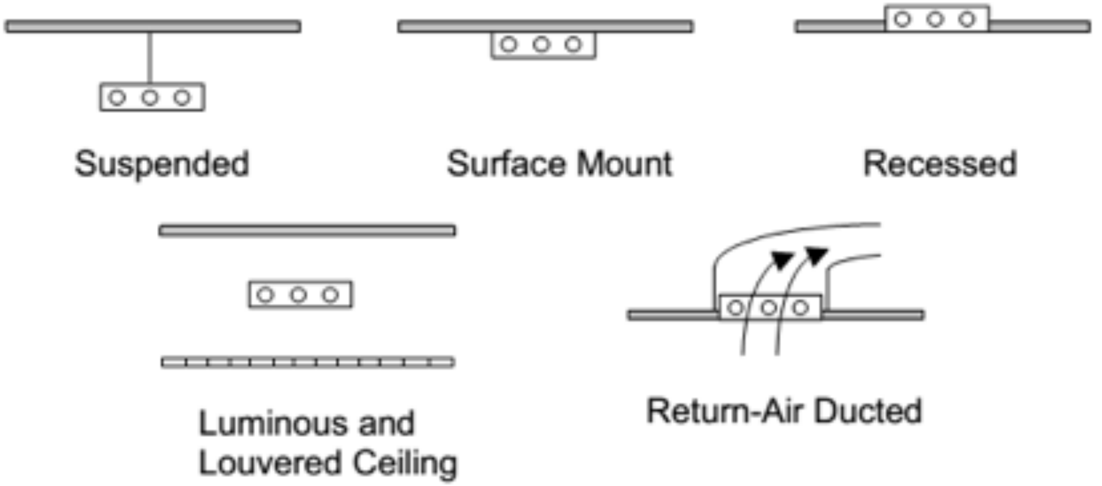
A. The lighting levels recommended by the Illuminating Engineer Society of North America (IESNA) shall be the established lighting standards. Examples of current IESNA lighting levels include:

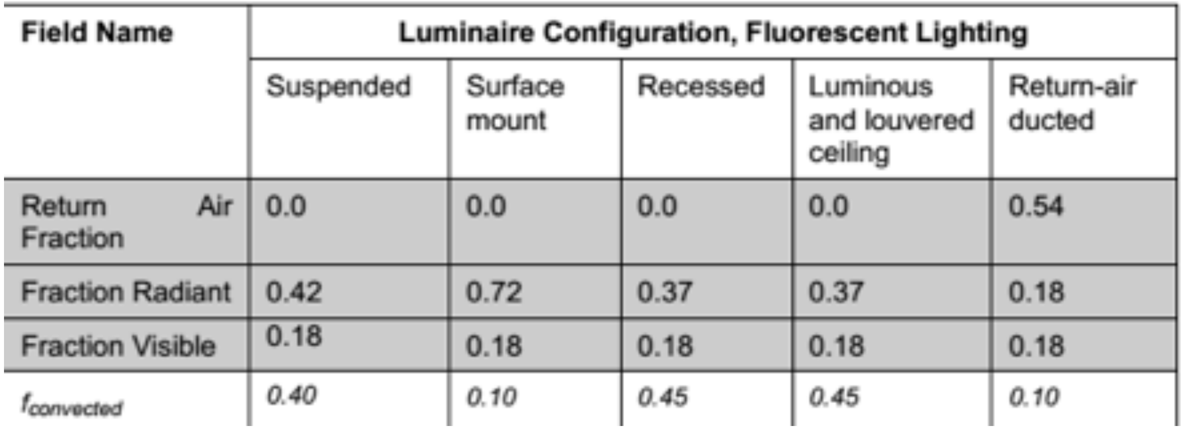
(a) offices, classrooms, and laboratories: 30-50 foot candles (depending on specific work tasks) on desk and table tops;
(b) hallways: 5-8 foot candles;
(c) stairwells: 5-8 foot candles;
(d) restrooms: 5-8 foot candles.

(1 ft-candle = 10.76 lux)

Lighting

$f_{convected}$ = 1.0 – (Return Air Fraction + Fraction Radiant + Fraction Visible)



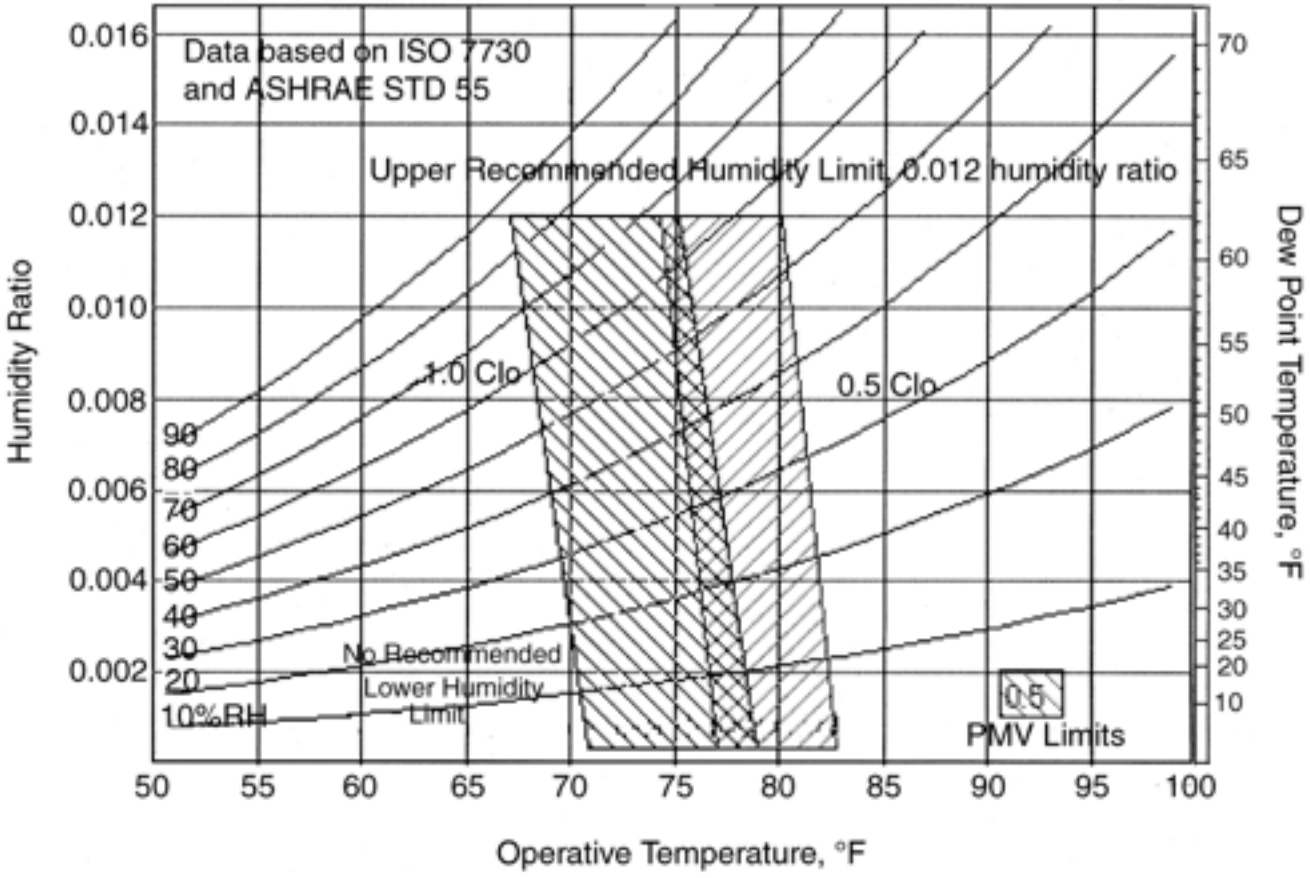


Field Name	Luminaire Configuration, Fluorescent Lighting				
	Suspended	Surface mount	Recessed	Luminous and louvered ceiling	Return-air ducted
Return Air Fraction	0.0	0.0	0.0	0.0	0.54
Fraction Radiant	0.42	0.72	0.37	0.37	0.18
Fraction Visible	0.18	0.18	0.18	0.18	0.18
$f_{convected}$	*0.40*	*0.10*	*0.45*	*0.45*	*0.10*

EnergyPlus. Input/Output Reference. p.360.
Lighting Handbook: Reference& Application, 8th Edition, Illuminating Engineering Society of North America, New York, 1993, p.355.

Temperature Setpoints

- UMD Policy X-12.00(A): 68°F-78°F (73°F ± 5°F)



ANSI/ASHRAE Standard 55-2004

Design Ventilation

- Minimum outdoor air fraction very important
- EnergyPlus options:
  - OA per person (default 20 cfm)
  - OA per floor area
  - OA per zone
  - OA air change per hour
- Use ~0.1-0.2CFM/ft^2 (or 20% design flow rate)
  - Look at floor plans & ASHRAE 62.1

HVAC

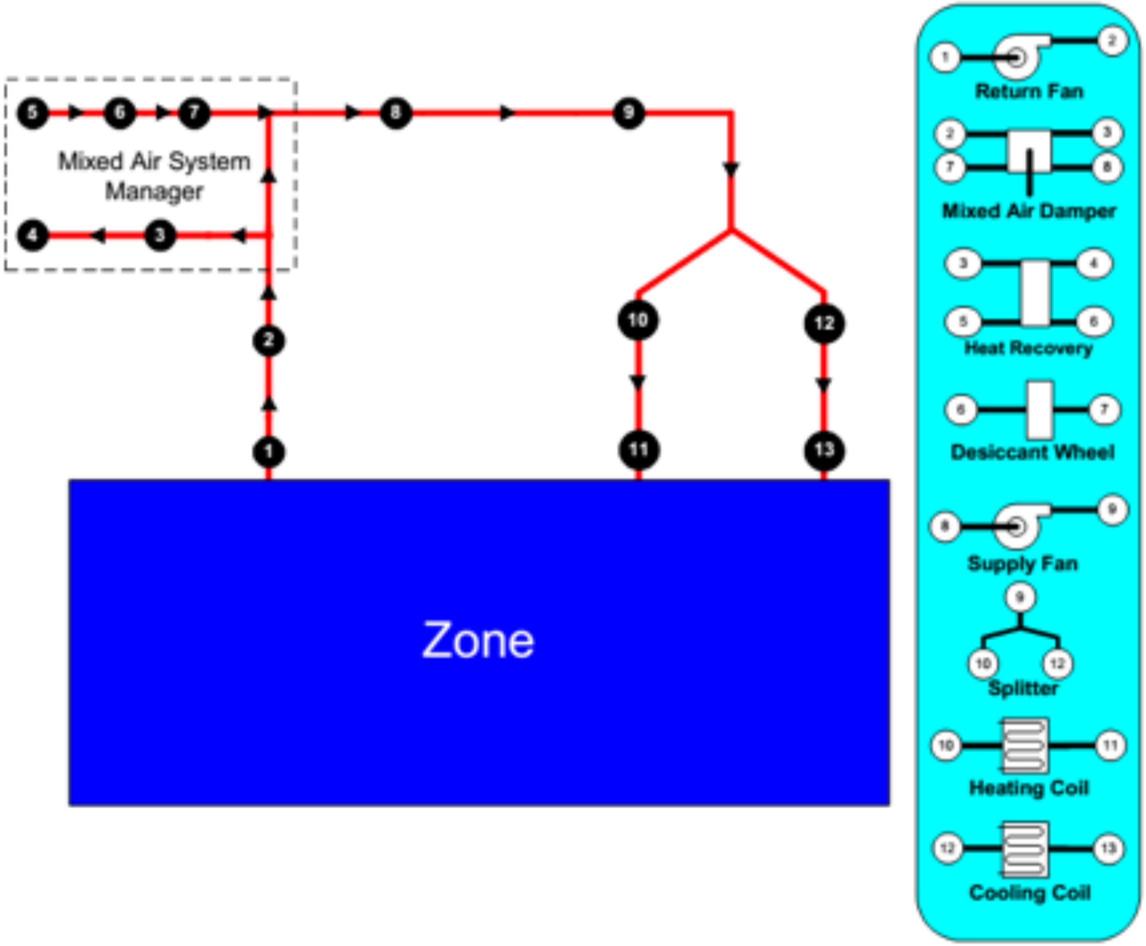


Figure 70. Example Node Diagram

EnergyPlus. Input/Output Reference. p.506.

HVAC

- Most UMD buildings are:
  - steam heat -> hot water (model as hot water)
  - CAV (some VAV)
  - DX cooling (some chilled water)

- Use default efficiencies, load curves (for now)

- Autosize equipment (for now)