Advanced Building Science

- Overview of Load Calculations
  - Principles
  - Types of calculations

- Heating Load Calculations
  - Overview of residential features
  - Heating load principles
  - General procedure
  - Pick-up loads

- Readings
  - HF: Chapter 17 – primary focus
  - HF: Chapter 18 – be familiar with generalized procedures & tables

Overview of Load Calculations

Overall Modeling Strategy

- Load Model
- Systems Model
- Plant Model
- Economic Model

Heating Load Calculations

Overview of Residential Features

- Typically conditioned (and possibly occupied) 24 hrs/day
- System loads are primarily imposed by heat loss through the envelope and by air exchange (infiltration & ventilation)
  - internal loads are small by comparison
- Usually conditioned as a single zone
  - so unit capacity cannot be redistributed from one area to another

Heat Load Calculations

Overview of Residential Features – cont'd

- Most heating/cooling units are relatively small in capacity
  - and operate at partial load conditions most of the year
- Dehumidification occurs only during cooling unit operation
- Multi-family units are similar to single family detached
  - but may not have sides exposed in all directions

Uses of Basic Load Fundamentals

- Material Comparisons
- Energy Compliance
  - overall thermal envelope heat loss
- Building Design Loads
- Energy Estimating

Calculating Design Heat Loads

A simplified approach to estimate loads for the "worst case" conditions that can reasonably be anticipated during a heating season.

- primary orientation is ensuring the heating equipment is "adequately" sized
- can be done for whole building or room by room

Why wouldn't we design for the most severe condition?

Safety Factors and Allowances

- Common Practice (in the past)
  - 10 to 20% oversizing allowances for pipe/duct losses
  - 10 to 20% for pick-up loads
  - other factors based on experience or concern of the designer

- Generally not necessary in well-insulated and airtight structures
  - Code *generally* limits oversizing

Generalized Procedure

- Select indoor and outdoor design conditions
  - estimate temperatures in adjacent unheated spaces
- Select or compute heat transfer coefficients
- Determine net area of all envelope components
- Compute heat transmission losses for each component
- Compute heat losses from grade-level slabs
- Compute the infiltration & ventilation heat losses
- Sum the transmission and infiltration/ventilation losses
- Consider pick-up loads

Heating Load – Design Conditions

- Outdoor design conditions
  - will the building be exposed to abnormal conditions
  - be mindful of wind
- Indoor design conditions
  - 72 degrees is common (max. for MN Energy Code)

Heating Load – Design Conditions

- Temperatures in Adjacent Spaces
  - A function of surface areas & heat transfer coefficients

- Common spaces
  - Garages
    - for many calculations, it is assumed to be at outdoor conditions
    - however, for insulated garages many will assume the mean
  - Attics
    - most times assume outdoor conditions (ASHRAE 17.11)
      - however, see procedure at ASHRAE 2013 17. 3
  - Crawl spaces
    - a special case, but the procedures in the book are really bad!

Transmission Heat Losses – Above Grade

- Heat loss through walls
- Heat loss through fenestration
- Heat loss through ceilings & roof
  - usually consider attic to be outdoor temperature

Transmission Heat Losses – Below Grade

- Heat loss is a function of soil temperature that is related to outdoor temperatures
  - less fluctuation
  - considerable lag

- Foundation components
  - below grade walls
  - below grade floors
  - slab-on-grade

Infiltration & Ventilation Losses

- Sensible
- Latent
  - not usually included in residential design heat load

Heating Load Calculations

- Heating Load Summary Form
  - Entire building
    - at a single point in time
  - Room by room
    - at room peak
    - at building peak
- Pick-Up Load
  - Poorly understood and documented
  - Somewhat controversial

Duct Losses/Gains

Table 6 Typical Duct Loss/Gain Factors

		1 Story						2 or More Stories					
	Supply/Return Leakage	11%/11%			5%/5%			11%/11%			5%/5%		
Duct Location	Insulation ft²·h·°F/Btu	R-0	R-4	R-8	R-0	R-4	R-8	R-0	R-4	R-8	R-0	R-4	R-8
Conditioned space		No loss ($F_{dl} = 0$)											
Attic	C	1.26	0.71	0.63	0.68	0.33	0.27	1.02	0.66	0.60	0.53	0.29	0.25
	H/F	0.49	0.29	0.25	0.34	0.16	0.13	0.41	0.26	0.24	0.27	0.14	0.12
	H/HP	0.56	0.37	0.34	0.34	0.19	0.16	0.49	0.35	0.33	0.28	0.17	0.15
Basement	C	0.12	0.09	0.09	0.07	0.05	0.04	0.11	0.09	0.09	0.06	0.04	0.04
	H/F	0.28	0.18	0.16	0.19	0.10	0.08	0.24	0.17	0.15	0.16	0.09	0.08
	H/HP	0.23	0.17	0.16	0.14	0.09	0.08	0.20	0.16	0.15	0.12	0.08	0.07
Crawlspace	C	0.16	0.12	0.11	0.10	0.06	0.05	0.14	0.12	0.11	0.08	0.06	0.05
	H/F	0.49	0.29	0.25	0.34	0.16	0.13	0.41	0.26	0.24	0.27	0.14	0.12
	H/HP	0.56	0.37	0.34	0.34	0.19	0.16	0.49	0.35	0.33	0.28	0.17	0.15

Values calculated for ASHRAE *Standard* 152 default duct system surface area using model of Francisco and Palmiter (1999). Values are provided as guidance only; losses can differ substantially for other conditions and configurations. Assumed surrounding temperatures:

Cooling (C): $t_o = 95°F$, $t_{attic} = 120°F$, $t_b = 68°F$, $t_{crawl} = 72°F$ Heating/furnace (H/F) and heating/heating pump (H/HP): $t_o = 32°F$, $t_{attic} = 32°F$, $t_b = 64°F$, $t_{crawl} = 32°F$

Source: ASHRAE Handbook Fundamentals 2013 Chapter 17.8

Table 16 Summary of Heating Load Calculation Equations

Load Source	Equation	Tables and Notes
Exterior surfaces above grade	$q = UA\Delta t$	$\Delta t = t_i - t_o$
Partitions to unconditioned buffer space	$q = UA\Delta t$	Δt = temp. difference across partition
Walls below grade	$q = U_{avg,bw} A (t_{in} - t_{gr})$	
Floors on grade	$q = F_p p \Delta t$	See Chapter 18, Equations (41) and (42)
Floors below grade	$q = U_{avg,bf} A (t_{in} - t_{gr})$	See Chapter 18, Equations (37) and (38)
Ventilation/infiltration	$q_{vi} = C_s Q \Delta t$	From Common Data and Procedures section
Total sensible load	$q_s = \Sigma q$	

Source: ASHRAE Handbook Fundamentals 2013 Chapter 17.13

In Summary

Questions and Discussion

Next Class

- Cooling Load Calculations
  - Principles & Considerations
  - Heat Flow Rates and Design Conditions
  - Generalized Procedures
  - Residential (simplified approach)

- Readings
  - Chapter 17 => primary focus
  - Chapter 18 => (review for procedures and tables)