ES 71- The Building Envelope

- Building Heat Transfer:
  - **R**- "resistance value" of building materials to heat flow
  - $R_T = R_{inside\ film} + R_1 + R_2 + \ldots R_{outsidefilm}$
  - **U-value**: "overall heat transfer co-efficient"

    (includes allowance for BOTH convection and conduction heat transfer.)

$$U = \frac{1}{R_T}$$

Building Heat Transfer Calculations

- **Q = (U) x (A) x (delta T)**

  where:

  Q: heat transfer rate in Btu/hour

  U: overall heat transfer co-efficient

  A: surface area in square feet

  delta T: temperature difference across surface; $T_{inside} - T_{outside}$

Building Heat Transfer Calculations

- Sample Calculations:

  For sample calculations- outside design = 30 F

  inside design = 70 F

  - **Walls:** wall area is 300 square feet

    wall is wood stud with R-11 insulation; approximate U = 0.08

  Q = U x A x delta T

  = 0.08 x 300 x (70 – 30) = 0.08 x 300 x 40

  = **960 Btu/hour**

Building Heat Transfer Calculations

- Sample Calculations:
  - **Windows:** window area is 300 square feet
    window is single pane; appx U = 1.10

  Q = U x A x delta T
  = 1.10 x 300 x (70 – 30) = 1.10 x 300 x 40
  = **13,200 Btu/hour**

NOTE THAT FOR SAME SURFACE AREA, GLASS HAS OVER 13 TIMES THE HEAT FLOW AS FOR R-11 INSULATED WALL !!

Building Heat Transfer Calculations

- **Annual Heating Energy Needs:**
  - "Degree Day" method:
    - ***The number of Heating Degree Days that accumulate over a 24-hour period is defined as the difference between 65 F and the average outside air temperature for that 24-hour period.***
  - Estimated Annual Energy Usage:
    - Relies on the assumption that buildings need supplemental heat when the temperature outsdie drops below 65 F
    - Correction factor needed due to buildings with significant internal loads

Building Heat Transfer Calculations

- **Annual Cooling Energy Needs:**
  - "Degree Hour" method:
    - ***The number of Cooling Degree Hours that accumulate over a 24-hour period is defined as the difference between 74 F and the average outside air temperature for that 24-hour period.***
  - Estimated Annual Energy Usage:
    - Relies on the assumption that buildings need cooling when the temperature outside rises above 74 F
    - Correction factor needed due to buildings with significant internal loads

Building Heat Transfer Calculations

- Estimated Annual Heating Energy Needs:

$$E_{annual} = \frac{Q_{design} \times (DD) \times (24) \times (C_d)}{1,000,000 \times (\text{delta } T)}$$

where:

E_{annual}	=	annual heating energy required (MMBtu)
Q_{design}	=	design heating load of building
DD	=	annual heating degree days for building
C_d	=	correction factor for internal heat
		(for "typical" Bay Area residences C_d =0.70)
delta T	=	design temperature difference (°F)

Building Heat Transfer Calculations

- Estimated Annual Heating Energy Costs:
  - 1 THERM = 100,000 Btu

Annual THERMs $= \frac{(E_{annual})(1,000,000)}{100,000 \times (\text{Furnace efficiency})}$

Annual $$ = (Annual THERMs) x ($/ THERM)

Building Heat Transfer Calculations

- Estimated Annual Cooling Energy Needs:

$$E_{annual} = \frac{Q_{design} \times (CDH) \times (C_d)}{1,000,000 \times (\text{delta } T)}$$

where:

E_{annual}	=	annual cooling energy required (MMBtu)
Q_{design}	=	design cooling load of building
CDH	=	annual cooling degree hours for building
C_d	=	correction factor for internal heat
		(for "typical" Bay Area residences C_d =0.90)
delta T	=	design temperature difference (°F)

Building Heat Transfer Calculations

- Estimated Annual Cooling Energy Costs:
  - KW/ton operating costs
    - Residential split systems- 1.8 kw/ton
    - Rooftop package systems- 1.6 – 1.8 kw/ton
    - Central plant systems- 0.8 – 1.4 kw/ton
      - "Water cooled"- 0.8 kw/ton
      - "Air cooled"- 1.4 kw/ton

Annual tons = $(E_{annual})(1{,}000{,}000)/12{,}000$

Annual KWH = (Annual tons)(System kw/ton)

Annual $$ = (Annual KWH) x ($/ KWH)

Building Heat Transfer Calculations

- Example:

Building estimated heating load = 60,000 Btu/hour
(from heat transfer analysis)

Climatic data:

Building is in Seattle: heating Degree Days = 4424
outside winter design = 23 F
desired inside design = 68 F
$C_d = 0.60$

Heating system data: natural gas fired furnace; efficiency = 77%; cost of natural gas is $ 0.85 per therm.

Find Annual Energy Cost for this building!

Building Heat Transfer Calculations

- Example problem:

$$E_{annual} = \frac{Q_{design} \times (DD) \times (24) \times (C_d)}{1{,}000{,}000 \times (\text{delta } T)}$$

$$= \frac{(60{,}000)(4424)(24)(0.60)}{(1{,}000{,}000)(68-23)}$$

= 84.9 MMBtu = 84,900,000 Btu

Annual THERMs = $\frac{\text{Annual Energy Usage}}{100{,}000 \times (\text{Furnace efficiency})}$

$$= \frac{(84.9)(1{,}000{,}000)}{(100{,}000)(0.77)} = 1102.6 \text{ THERMS}$$

**Annual $$** = (Annual THERMS)($ per THERM)
= (1102.6)($0.85/THERM)
= **$ 937.21**