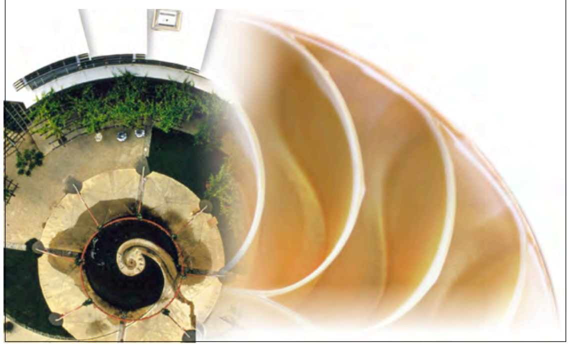
Heat Transfer and the Building Envelope

ARCH 331/431 Spring 2008
Lecture 6



announcements 4/17/08

A3: Envelope Heat Transfer

Assignment: Available later today (course website)

References: Available by this weekend (course website)

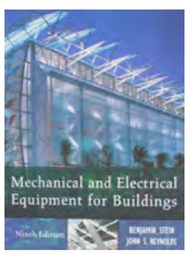
Due: week 5

Quiz 2: Tuesday 4/22

Assigned Readings by Section (not page)

9th Edition
Chapter 4
Thermal Properties of Building and Insulations Materials (beginning on page 147)

10th Edition
Appendix E
Thermal Properties of Materials and Assemblies (beginning on page 1547)



Architectural Sailing
(a hypothetical example)

Conventional Mechanical System: MECHANICIAL HEATING (45, 55) | MECHANICAL VENTILATION AND COOLING (65, 75, 85, 95)

Indoor "comfort zone" temperatures: 68 – 80

"Mixed-Mode" Mechanical System: CLOSED HEATING (45, 55) | OPEN (65, 77) | CLOSED COOLING (85, 95)

Closed Heating Mode Strategies

MECHANICAL
- Active Solar
- Furnace/Boiler

ARCHITECTURAL
- Thermal Mass: Heat
- Direct Gain: Sun

Closed Cooling Mode Strategies

ARCHITECTURAL
- Thermal Mass: "Coolth"
- Evaporation: Water

MECHANICAL
- Ceiling Fans
- Chillers

Seattle 2-hour temperatures

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
12 midnight	37	40	42	45	50	56	60	60	56	49	42	38
2	37	39	40	43	49	54	58	58	54	48	42	37
4	36	38	39	42	47	53	56	57	53	47	41	36
6	35	37	39	41	46	52	55	56	52	46	40	36
8	36	39	40	43	48	54	57	58	54	47	41	37
10	41	44	47	51	57	62	67	67	62	54	46	41
12 noon	44	48	51	55	61	67	72	72	67	58	49	44
2	45	50	53	57	64	70	75	75	69	60	51	45
4	44	48	52	56	62	68	74	74	68	59	50	44
6	42	46	48	52	59	64	69	69	64	55	47	42
8	40	43	45	48	54	60	64	64	60	52	45	40
10	38	41	43	46	52	57	61	62	57	50	43	39

8am to 6pm

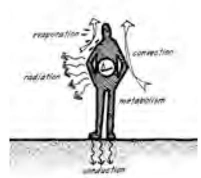
CLOSED/Heating: 55%
OPEN/"Sailing": 42%
CLOSED/Cooling: 3%

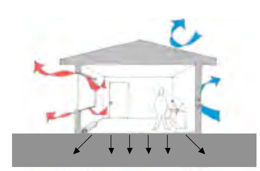
Balance Point = 55° F
Change-over Temperature = 75° F

Balance Point Temperature

Thermal Equilibrium between Inside and Outside

$Q_{losses} = Q_{gains}$ or $Q_{out} = Q_{in}$





Envelope ("skin") losses
Infiltration ("lung") losses
Perimeter ("feet") losses

Balance Point Temperature

Thermal Equilibrium between Inside and Outside

$$Q_{in} = Q_{out}$$

$$Q_{gains} = Q_{losses}$$

$$Q_{gains} = Q_{free} + Q_{purchased} = Q_{losses}$$

Q_{free} = *people + lights + equipment (and sun!)*

$Q_{purchased}$ = *purchased heat (boiler, furnace, etc.)*

$$Q_{losses} = UA \times (T_{in} - T_{outside}) = UA \times \Delta T$$

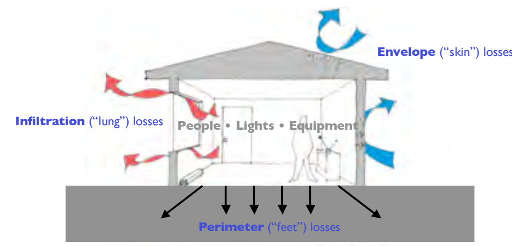
Balance Point Temperature:

$$T_{balance\ point} = T_{in} - Q / UA$$

Heat Transfer through the Building Envelope

$$Q_{losses} = Q_{gains}$$

envelope + infiltration + perimeter = people + lights + equipment



Thermal Envelope

"Insulate before insolate"

- Keep the heat in and the cold temperatures out in the winter.
- Keep hot temperatures out during the summer.

In California: Title 24 Energy Code

Elsewhere in the US: ASHRAE 90.1

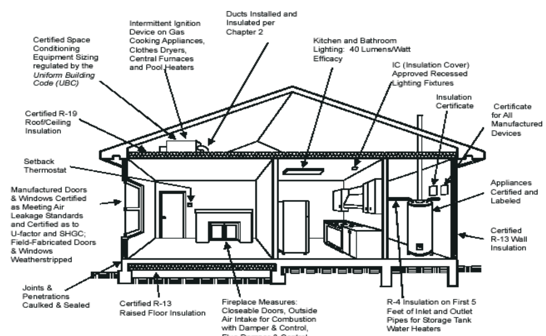
Title 24 (California) Mandatory Measures:

The mandatory measures represent a minimum level of efficiency. To achieve compliance with other parts of the standards, higher levels of efficiency may be required.

Roof/Ceiling: R-19

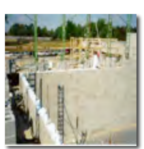
Walls: R-13

Floors: R-13



Insulation

BATT:
fiberglass, mineral wool



FOAM:
air-krete, enduratite

RIGID BOARD:
polystyrene, polyurethane

LOOSE FILL:
cellulose, fiiberglass

Insulation

minimize conductive heat transfer or heat flow to the outside

Resistance

- R-value
- Units: (hr sf °F) / Btu
- Resistivity - (r) per unit thickness

Conductance

- U-values (and C-values)
- Units: Btu / (hr sf °F)
- Conductivity - (k) per unit thickness
- Conductance - (C) = 1/R

Heat Transfer and the Building Envelope

Predicting Building Heat Transfer Under Steady State Conditions:

Q_{losses} = heat loss due to:

Step 1. Envelope ("skin") or $UA_{envelope}$ $\times \Delta T$
Step 2. Infiltration ("lungs") or $\text{"UA"}_{infiltration}$ $\times \Delta T$
Step 3. Perimeter ("feet") or $\text{"UA"}_{perimeter}$ $\times \Delta T$

$$Q_{losses} = UA_{ref} \times \Delta T$$

where $UA_{ref} = UA_{envelope} + \text{"UA"}_{infiltration} + \text{"UA"}_{perimeter}$

Determining Whole Building $UA_{(ref)}$

ENVELOPE:	walls, floor, roof, windows, doors, etc.	UA	U × A BTU/hr ft² °F × ft²
INFILTRATION:	air exchange via leaks, cracks and ventilation	"UA"	VHC_{air} × Volume × ACH .018 BTU/ft³ °F × ft³ × no./hr
PERIMETER:	loss through the ground via floor slabs, footings and basements	"UA"	F × P (BTU/hr ft °F) × (ft)

U The conductive heat loss coefficient for a series of materials (layers), such as heat transfer through the interior air film, gypsum board, insulation, exterior siding and exterior air film.

A Surface area of building element.

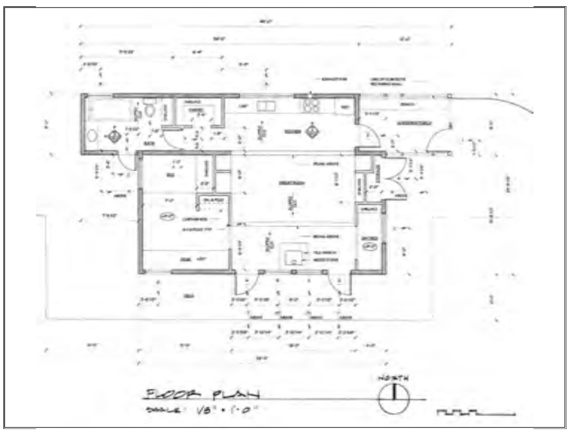
UA_{ref} The reference "UA" which is a sum of the three major routes of heat transfer.

VHC The Volumetric Heat Capacity of air, which is equivalent to the specific heat, or ability of air to store energy (like themal mass).

F This is an empirically derived constant found by referring to Table 4.8, pg. 165.

P Is the linear measure of the entire perimeter of the building.

ACH The Air Changes per Hour usually estimated by assessing the relative tightness of the building, and using Table 4.23 pg. 188.



Farnsworth House
Plano, Illinois
Mies Van der Rohe, 1946 - 1951

Chicago Design Conditions

(Plano is ~50 miles WSW of Chicago)

Winter Design Temp. (97.5%)	-4°F
HDD65°F	6013
Summer Design Temp. (2.5%)	89/74