Designing for Heating and Cooling

This Week's Presentation

> *Environmental Design à Go-Go!*
> Trends Towards Sustainability in Europe
> Presented by Anne Mainz

> Review: Worksheet #6

> **MEEB:** *Designing for Heating and Cooling, Part 1;*

> Worksheet #7;

> **First Analysis Project (Envelope Calculations)**

> This Week's Media Material: *Green for All;*

So On With The Show!

Last Week: **Heat Flow** (Chapter 7)

Worksheet #6

... 1. Provide appropriate examples of envelope constructions or components that serve as:

(a) a barrier to water = Roofing; Wall Siding; Closed Window

(b) a switch to sound = Operable Door or Window

(c) a connector to relative humidity = Open Door or Window; Cracks in Walls; Vapor-permeable Wall.

(d) a filter to solar radiation = Window Curtains or blinds; Transclucent glazing; Fabric Roof.

Last Week: **Heat Flow** (Chapter 7)

Worksheet #6

... 2. Conductance is best described as:

(a) a direct measure of the ability of a unit thickness of material to resist heat flow

(b) a direct measure of the ability of a unit thickness of material to permit heat flow

(c) a direct measure of the ability of any stated thickness of material to permit heat flow

(d) a direct measure of the ability of any stated construction assembly to permit heat flow

Last Week: **Heat Flow** (Chapter 7)

Worksheet #6

... 3. Based upon the trends in envelope design discussed in the book, it would be accurate to say:

(a) the R-values of envelope constructions have not really changed in the past 50 years

(b) the R-values of envelope constructions have decreased during the past 50 years

(c) the R-values of envelope constructions have increased during the past 50 years

(d) R-value, as a measure of thermal barriers, has been replaced by emittance

Last Week: **Heat Flow** (Chapter 7)

Worksheet #6

... 4. Norberg-Schulz is noted for his:

(a) research work leading to ASHRAE/IESNA Standard 90.1

(b) research into the characteristics of "superwindows"

(c) work as a consultant on numerous LEED-rated green building projects

(d) clarification of the roles of and intents for building envelope elements

Last Week: **Heat Flow** (Chapter 7)

Worksheet #6

... 5. To calculate the heat loss through an opaque wall at any given time generally requires which of the following information sets:

(a) wall area and U-factor, and the temperature difference across the wall

(b) wall thickness and area, and the date and time of day

(c) wall area, resistance and emittance, and the fenestration heating rating (FHR)

(d) wall area and U-factor, and the solar heat gain coefficient

Last Week: **Heat Flow** (Chapter 7)

Worksheet #6

... 6. Which of the following lists is most indicative of the features that have helped to improve the thermal performance of windows:

(a) low-U coatings, inert frame materials, and selective-resistance films

(b) smaller units, larger frames, and clearer glass

(c) inert gas fills, low-ε coatings, and selective transmission films

(d) higher U-factors, higher ε-values, and higher transmission capabilities

Last Week: **Heat Flow** (Chapter 7)

Worksheet #6

... 7. U-factor (the overall coefficient of thermal transmission) is calculated by which of the following equations:

(a) $U = (R1 + R2 + R3 + ...)$

(b) $U = (R1 + R2 + R3 + ...) / 1$

(c) $U = 1 / (R1 + R2 + R3 + ...)$

(d) $U = (R1) (R2) (R3) (...)$

Last Week: **Heat Flow** (Chapter 7)

Worksheet #6

... 8. Water vapor will always flow through the building envelope:

(a) from lower to higher elevations

(b) from colder to warmer temperatures

(c) from inside to outside

(d) from higher vapor pressure to lower vapor pressure

Last Week: **Heat Flow** (Chapter 7)

Worksheet #6

... 9. Exterior shading devices are generally more effective than comparable interior shading devices:

(a) because exterior devices are more durable

(b) because exterior devices can intercept solar radiation before it enters a building

(c) because exterior devices can be easily coated with selective surface coatings

(d) because exterior devices block shortwave radiation and interior devices block longwave radiation

Designing for Heating and Cooling
Part I
(Chapter 8.1 > 8.7)

This week... Designing for Heating and Cooling

MEEB: The Transition to Design

Up until now, we have discussed concepts which allow us to collect data about the environment and data about building systems which relate to the thermal behavior of buildings.

We have learned, too, about the variables which affect the built environment and about human comfort.

We have seen different criteria by which to choose goals for the control of thermal systems.

Now what? ***Design.***

This week... Designing for Heating and Cooling

MEEB: The Transition to Design

Our text presents the methodology of design from the general to the specific.

Our text also distinguishes between two types of environmental system "types":

Conventional Buildings;
Buildings using on-site Resources.

What are the differences between them? Do these categories represent two distinct building types or different methodologies which might be effectively combined?

This week... Designing for Heating and Cooling

MEEB: Organizing the Problem

Which building elements should contribute to Heating or Cooling?

Keep in mind that...

Interior heat sources can contribute towards heating;
Daylighting can reduced interior heat sources to cool;
Insolation can contribute towards heating;
&c.

So let's consider the following:
Fenestration; Building Form; Building Envelope.

This week... Designing for Heating and Cooling

MEEB: Organizing the Problem

Fenestration

Codes often prescribe required fenestrated areas based on floor area (residential) or wall area (non-residential), under the assumption of conventional heating or cooling. Prescribed areas are relatively small. To justify designing with larger areas of fenestration, some benefit must be anticipated.

We must consider the "trade-offs" between lighting, energy loss/gain, and psychological benefits due to increased fenestration.

This week... Designing for Heating and Cooling

MEEB: Organizing the Problem

Fenestration

Is there an Optimum quantity of fenestration in buildings?

Introduction of fenestration might be weighed along with typical energy uses for conventional buildings:

For example: 30% space heating; 11% space cooling; 14% electric lighting.

One's implementation of fenestration will effectively determine these proportions; heating/cooling design proceeds accordingly.

This week... Designing for Heating and Cooling

MEEB: Organizing the Problem

Building Form *Tall or short; Thick or thin?*

> Internal-load Dominated (ILD) Buildings (Fig. 8.1)

Tall Thick Buildings
Short Thick Buildings

Tall Thick Buildings with Atria
Short Thick Buildings with Atria

Consider the implications for Daylighting, Heating, and Cooling

This week... Designing for Heating and Cooling

MEEB: Organizing the Problem

Building Form *Tall or short; Thick or thin?*

> Skin-load Dominated (SLD) Buildings (Fig. 8.2)

Tall Thin Buildings
Short Short Buildings

Consider the implications for Daylighting, Heating, and Cooling

This week... Designing for Heating and Cooling

MEEB: Organizing the Problem

Building Form Questions -- Daylighting

> *Relative importance of Sidelightings and Top-lighting?*
> *Role of direct sun in Daylighting?*
> *Seasonal Adjustments?*
> *Daily Adjustments?*
> *Evenness of Adequate Daylighting?*

This week... Designing for Heating and Cooling

MEEB: Organizing the Problem

Building Form Questions -- Heating

> *Can the Sun heat spaces? How will south-wall design contribute?*
> *Can walls facing other directions be minimized?*
> *How low a U-factor can be afforded?*
> *Is sunlight already being introduced for Daylighting?*
> *Can incoming fresh air be tempered?*
> *Are there heating sources to aid heating of perimeter spaces?*

This week... Designing for Heating and Cooling

MEEB: Organizing the Problem

Building Form Questions -- Cooling

> *Will the building be open to breeze or closed to retain “cool”?*
> *Can direct sun be kept out? Can east/west windows be minimized?*
> *Can daylight be introduced without overheating?*
> *Can cooling be provided by outside air, rather than refrigeration?*
> *Can refrigeration mechanism be operated during off-peak hours, when power is cheapest?*
> *Can incoming fresh air be tempered?*
> *Can building structure absorb excess heat during the day, and expell it at night?*

This week... Designing for Heating and Cooling

MEEB: Organizing the Problem

Building Envelope

Different orientations require different consideration. **Duh!** (But most architects really do ignore this challenge.)

Figure 8.3: An array of solutions for each orientation.

Figure 8.4: The full suite of lighting, heating, and cooling considerations combine with structural and acoustic decisions: *Structure (thermal mass); Ventilation (thermal mass); Daylighting (lightshelf and calibrated openings); Artificial lighting (indirect); Sound Absorption.*

This week... Designing for Heating and Cooling

MEEB: Zoning

What is "Zoning" in the context of Environmental System?

Zoning is influenced by: **Function, Schedule,** & **Orientation.**

(Orientation might also be redefined as "configuration" -- Fig. 8.5)

What are some examples of each in the context of building planning and Environmental Systems?

This week... Designing for Heating and Cooling

MEEB: Daylighting Considerations

Daylight Factor: “percentage of the outdoor illuminance *under overcast skies* that is available indoors.

$$DF = \frac{\text{indoor illuminance from daylight}}{\text{outdoor illuminance}} \times 100\%$$

Guidelines for target daylight factors are covered elsewhere in the textbook. These criteria involve two factors: *How high is the window is on the wall; how large is the window or skylight area compared to the floor area?*

Remember: *More light is available in the summer; controlling direct sun is a necessary consideration.*

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

For passive solar heating, energy conservation is the first consideration. "Insulate before you insolate." *What does that mean?*

Whole-Building Heat Loss Criteria:

Table 8.3: Guideline for maximum rate of heat loss.

What is a **Degree Day**? *"A unit of measurement equal to a difference of one degree between the mean outdoor temperature on a certain day and a reference temperature, used in estimating the energy needs for heating or cooling a building." (Often summed over a period of time, such as a year or a heating/cooling cycle.)*

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

Whole-Building Heat Loss Criteria

> Rates shown for two situations:
> *1) Conventional Small Buildings; (p. 223)*
> *2) Passively Solar-Heated Buildings*

> For the first case, overall rate of Btu/DD ft^2 is based upon total heat loss, including all portions of the envelope and infiltration.

UA: "Relative Heat Loss", based on U x A;

> For below-grade conditions, designers may approximate heat loss, for instance U x $^1/_2$ A.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

Whole-Building Heat Loss Criteria | *Conventional Small Buildings*

> UA for infiltration: ACH x Constant (a factor determined by density and specific heat, ~ 0.018 for imperial units)

Overall Heat Loss

$$\frac{(UA_{envelope} + UA_{infiltration}) \times 24h}{\text{total heated floor area}} = \text{Btu/DD ft}^2$$

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

Whole-Building Heat Loss Criteria | *Passively Solar-Heated Buildings*

> The rate of Btu/DD ft^2 **excludes** the solar-collecting portions of the envelope.

$$\text{Overall Heat Loss } \frac{(UA_{\text{envelope, except solar gain areas}} + UA_{\text{infiltration}}) \times 24h}{\text{total heated floor area}} = \text{Btu/DD ft}^2$$

> For both types of buildings, the assumed rate of infiltration is the hardest to predict correctly. Well-built, small buildings can easilty achieve ACH 0.75; additional care to detailing and sealing has afforded levels below 0.33.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

Whole-Building Heat Loss Criteria | *Passively Solar-Heated Buildings*

*"Passive solar heating and energy conservation have a complex relationship. Relative to conventional buildings, passively solar-heated buildings usually conserve purchased energy; yet, buildings that aim at very high percentages of solar heating can use more **total** heaing energy than is used by buildings with smaller window areas. Designers interested primariloy in saving purchased energy may aim at lower solar percentages and more insulation;designers interested in buildings that closely relate to climate and climactic changes may aim at higher solar percentages (and more daylighting) along with higher thermal masses and, probably, greater ranges of indoor temperature." p. 227*

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

The **Solar Savings Fraction** (SSF) allows us to evaluate a building's solar heating performance.

> *How much does the solar design reduce the building's "auxiliary" energy requirement relative to a reference building?*

SSF is not the percentage of building heating supplied by the sun; rather, SSF is a measure of a building's "conservation advantage," including factors such as waterheating, lighting, etc.

> Table F.1 "A starting point for passive solar preliminary design." This gives a range of expected performance relating location to SSF performance with simply glazing categories.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines
Solar Savings Fraction (SSF)

> Fig 8.09: Chart relating SSF to glass/floor area ratio.

> Fig 8.10: Required heating based on different glazing installations.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

Thermal Mass must be factored in to determine SSF. Recall the three categories of solar heating: *direct gain, indirect gain, isolated gain.*

Table F.2: The relationship between SSF and the area (or weight) of water or masonry to provide for *direct-gain* designs.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

> *Distribution of the Thermal Mass is also important.*

For indirect gain installations, the thermal mass is in full sun, for the entire date. For direct-gain installations, the thermal mass is within the inhabited space; the exposed surface of the mass should be three times the glazing area.

Thicknesses of masonry surfaces above 4” to 6” contribute less to the thermal behavior of direct-gain systems.

In low SSF configurations, the thermal mass has little role; but with increasing SSF values, the proportion of thermal mass should increase.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

Phase-change materials are an alternative to simple thermal mass installations.

PCMs can be broadly grouped into two categories; ”Organic Compounds“ (such as waxes, vegetable extract, polyethylene glycol) and “Salt-based Products” (such as Glauber’s salt). The most commonly used PCMs are salt hydrates, fatty acids and esters, and various paraffins (such as octadecane). Recently also ionic liquids were investigated as novel PCMs.

As most of the organic solutions are water free, they can be exposed to air, but all salt based PCM solutions must be encapsulated to prevent water evaporation. Both type offers certain advantages and disadvantages and if they are correctly applied some of the disadvantages becomes an advantage for certain applications.

Eutectic salts have been used since the late 1800s as a medium for the thermal storage applications. They have been used in such diverse applications as refrigerated transportation for rail and road applications and their physical properties are, therefore, well-known.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

PCM Rule of Thumb: "Tile surface area = 1 to 3 times the area of solar opening." p.230

Other materials use for collecting/absorbing solar gain include rock beds below a concrete floor slab.

* * *

Orientation: Due South -- or at least within 30°

Increasing penalties upon SSF for deviation from true south as follows: 5% decrease at 18° east or 30° west; 10% decrease at 28° east or 40° west; 20% decrease at 42° east or 54° west;

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

Roof Ponds: Used in dryer, warmer regions, with higher sun altitudes, without threat of snow.

Typically implemented for *cooling's* sake...

Nevertheless, *"in the US southern latitudes, a pond sized for cooling will usually be adequate to absorb the needed winter sun."*

Size Guidelines: *85% to 100% floor area for winter average temperatures of 25° to 35°*

60% to 90% floor area for winter average temperatures of 35° to 45°

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Guidelines

Active Solar Heating: These systems use pressurized systems, the orientation of which might be adjusted dynamically for optimum exposure, to collect, store, and transfer solar energy to the building spaces.

Rule-of-thumb Guidelines:

Collector/FloorArea = “smaller of window/floor-area ratios indicated on Table F.1”

Optimum Tilt (from horizontal): Latitude plus 10° to 15°
Optimum Angle (Azimuth): due South to 15° W of South

This week... Designing for Heating and Cooling

MEEB: Summer Heat Gain Guidelines

Cooling relates more intimately to building design configurations.

Cross Ventilation
Stack Ventilation
Night Ventilation of Thermal Mass
Evaporative Cooling (Active)
Cooltowers (Passive, Evaporative)
Roof Ponds
Earth Tubes

Each design guideline has a corresponding "Detailed Calculation Procedure."

This week... Designing for Heating and Cooling

MEEB: Summer Heat Gain Guidelines

Cross Ventilation

Maintains a building at slightly higher temperatures than those outdoors.

Provides plentiful fresh air.

Sufficient inlet area must be provided;
equal (or greater) outlet area must be provided.

Interior obstructions must also provide openings of equal area for air movement.

Additional assumptions must be made concerning wind direction.

This week... Designing for Heating and Cooling

MEEB: Summer Heat Gain Guidelines

Stack Ventilation

Also maintains a building at slightly higher temperatures than those outdoors.

Provides plentiful fresh air.

Sufficient inlet area must be provided;
equal (or greater) outlet area must be provided.

Stack cross sectional area must match these inlet/outlets.

This week... Designing for Heating and Cooling

MEEB: Summer Heat Gain Guidelines

Night Ventilation of Thermal Mass

Maintains a building at lower temperatures than those outdoors during the day; flushes the building with cool fresh air during the night.

Hours of “closed” and “open” operation must be determined:
Closed at 6am (for 100° max day) or at 8am (for 85° max day);
Opened when outdoor temperature drops below 80°

Heat removal during “open” hours may be aided by mechanical means, such as fans. Ventilation rate may be determined by “best hour” of cooling (ie, time at which temperature difference is the greatest).

This week... Designing for Heating and Cooling

MEEB: Summer Heat Gain Guidelines

Evaporative Cooling

Fan-forced air through a wet filter. Useful primarily in hot, dry climates. Fan consumes energy, and establishes a economic “threshold” below which this method is inappropriate.

No use of chemical refrigerants required.

This week... Designing for Heating and Cooling

MEEB: Summer Heat Gain Guidelines

Cool Towers

A variation on the "Evaporative Cooling," Cool Towers allow the introduction of air cooled by moist filters in at a high elevation; the cooler air then falls into the body of the building. Although provision for the escape of exhaust air must be provided, the Cool Tower needn't be paired with a solar chimney or equivalent building feature to be effective.

This week... Designing for Heating and Cooling

MEEB: Summer Heat Gain Guidelines

Roof Ponds

Also unlikely to be implemented in most temperate climates in the US, this method of cooling does provide for very stable temperatures. Average water depth need not be more than 3" to 6".

Criteria for Roof Pond area include:
- Pond Maximum Temperature (usually 80°)
- Pond Minimum Temperature (usually night minimum DB)
- Pond Delta-T (the difference between the above)
- Ponds allowable daily stored heat --
  - 70% from building, 30% from above through insulation.

Analogies to Roof Ponds may be made in the effect of planted, "Green" roofs with their moistened soils.

This week... Designing for Heating and Cooling

MEEB: Summer Heat Gain Guidelines

Earth Tubes

Q: What the hell is it?
A: It's sort of the equivalent of air-based geothermal heating.

The efficacy of this method depends not only on the tube length, tube diameter, and earth temperature, but also upon soil thermal conductivity, which may vary over a small area but all which may vary over time.

Essentially, the cooling afforded by the Earth Tube upon the forced air in combined with other cooling and heating influences withing the building envelope.

This week... Designing for Heating and Cooling

MEEB: Reintegrating Daylighting, Passive Solar Heating, and Cooling

After proceeding through both prescriptive conservation approaches and passive solar studies, through envelope investigations and review of fenestration/floor-area relationships, it is possible that conflicting directions may be indicated.

This is normal; this is Architectural Design.

Choices about all of the above must be made in concert with the designer's personal interests and knowledge, as well as balanced by the local traditions and client's acceptance.

"When prescriptive standards... appear to preclued either passive solar heating or... cooling strategies in a building, ... remember that there are trade-offs (in which more insulation... might allow more glass areas) or methods to compare whole-building annual energy consumption."

This week... Designing for Heating and Cooling

Next in MEEB: Calculating Worst-Hourly Heat Loss

Now in Class:

Worksheet #7:
Designing for Heating and Cooling

(Chapter 8.1 > 8.7)

Project #1:
Design | Analysis | Design

Step 2: Envelope Calculation Review

This week... Designing for Heating and Cooling

Project #1: Design | Analysis | Design ***Schedule***

Discussed 27 Feb.	Project Data and Discussion;
Due Last Week	Initial Sun Shading Solutions, including shade device; Shading Mask for Shade Device.
Due for Today	Initial Material Design for Opaque Walls; Heat Flow Analysis for Opaque Walls.
Due for 19 March	Initial Design Study of Transparent Elements; Heat Flow Analysis for Transparent Elements; Composite Envelope Heat Flow Analysis.
Due for 2 April	Heating and Cooling Calculations; Solar Savings Fraction.

Viva la Revolucione!

PBS Video Series: ***Design E^2***

This week's showing: Green For All

This week... Cradle to Cradle: Chapter 6

Putting Eco-Effectiveness into Practice