TAKE III

Designing for Heating and Cooling

This Week's Presentation

> *Roadmap for the Rest of the Semester*

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

> Worksheet #7;

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

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

> Worksheet #8;

Avanti Popolo!

Roadmap for the Rest of the Semester

> We've worked extensively with theoretical material from two directions: The technical/analytical focus and the conceptual/ethical imperative towards Sustainability.

> But... **Why was *I* still confused?**

Maybe: I'm here not as a theoretician but as a *practicioner*.

Now that we have heard how Environmental Systems might be conceived, we need to get a bit dirty:

How are they conceived right now -- in the "real world"?

Roadmap for the Rest of the Semester

> We’re going to round out our theoretical framework with the discussion of “design” for heating and cooling, which we postponed from last month.

> But, starting next week, we’re going to shift gears, and to examine an actual building from the perspective of a professional Architect, who works with developer clients to build middle-income housing or speculative commercial projects.

> We’ll encounter the actual graphic language of MEP plans, the typical systems required for a complete project, and the responsibilities demanded of an ARCHITECT in those systems coordination.

Roadmap for the Rest of the Semester

> April 9th: **M** HVAC for Smaller Buildings

> April 16th: **P** Plumbing

> April 23rd: **E** Electrical

> April 30th: Environmental Systems for Larger Buildings:
> (HVAC, Vertical Transport, &c.)

> May 7th: Synthesis and Review

... Goodbye Green Brick Road...!

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... <u>Designing for Heating and Cooling</u>

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.

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

> 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 fol-lows: 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)

Viva la Revolucione!

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

This week's showing: Green For All

Designing for Heating and Cooling
Part II
(Chapter 8.8 > 8.14)

This week... Designing for Heating and Cooling

MEEB: Calculating Worst-Hourly Heat Loss

We have discussed how heat energy moves through a building envelope (q) and through the introduction of ventilation (q_v). For heat loss in winter, these may be combined.

"The total hourly heat loss of a building can be calculated under several different assumptions reflecting different purposes." p.254

Maximum Hourly Loss: Sizing Conventional Heating Equipment
Maximum Hourly Loss: Sizing Auxiliary Heating for Passive Solar
Maximum Hourly Loss: Checking Design Criteria
Maximum Hourly Loss: Hourly Rates of Fuel Consumption

This week... Designing for Heating and Cooling

MEEB: Calculating Worst-Hourly Heat Loss

Sizing Conventional Heating Equipment

This calculation of $q+q_v$ is intended to find the MAXIMUM amount of heat-per-hour that the equipment must provide.

Based on two assumptions:

1) No internal heat gains; no solar gains.
2) The *design* lowest temperature is occurring. (So that no fewer than 97.5% of the days see no temperature lower than this figure.)

These factors are conservative, and result in equipment over-sized for most occasions throughout the year.

This week... Designing for Heating and Cooling

MEEB: Calculating Worst-Hourly Heat Loss

Sizing Auxiliary Heating for Passive Solar

Based on the following assumptions:

1) No internal heat gains;
2) The *design* lowest temperature is occurring. (So that no fewer than 97.5% of the days see no temperature lower than this figure.)

But:

3) "...sufficient stored solar energy to at least cancel out the heat losses through the south solar collection area." p.254

This week... Designing for Heating and Cooling

MEEB: Calculating Worst-Hourly Heat Loss

Sizing Auxiliary Heating for Passive Solar

What does this mean? At least for the envelope of the south-facing "collection area" of the building, no additional heating capacity need be provided.

BUT: On days during which solar loads are weak (such as overcast days), this method might result in insufficient heating. Most designers prefer to use the former method even if doing so results in over-sized systems.

"No one ever got fired for buying IBM" -- Ancient Folk Saying.

This week... Designing for Heating and Cooling

MEEB: Calculating Worst-Hourly Heat Loss

Checking Design Criteria

Calculations of q and q_v values can also be useful in retrospect, to point out opportunities for improving a system already designed.

"Redesign of building envelopes to meet such criteria is fairly common in the early stages of a building design." p225.

This week... Designing for Heating and Cooling

MEEB: Calculating Worst-Hourly Heat Loss

Hourly Rates of Fuel Consumption

During the heating season, a building's environmental system will begin to consume fuel to provide heat to the interior. The rate of fuel consumption depends, directly, upon the rate of heat loss from the interior space. If the equipment is designed for the *critical* winter design temperature, at (typical) higher temperatures, the system will cycle -- ie, run intermittently.

HOWEVER: Energy suppliers need to know the maximum rate, based on the maximum heat loss.

This week... Designing for Heating and Cooling

MEEB: Calculating Heating-Season Fuel Consumption
(Conventional Buildings)

"Internal and solar gains make almost any building warmer than the outdoors during the heating season. The [heating system] is not needed until the outdoor temperature drops to the point at which these internal and solar gains are insufficient to heat the building by themselves, that is, when the heat loss through the building's skin and infiltration matches the heat gained through solar plus internal loads. ***This particular outdoor temperature is called the balance point****; it represents the beginning of the need for space-heating equipment." p.256*

This week... Designing for Heating and Cooling

MEEB: Calculating Heating-Season Fuel Consumption
(Conventional Buildings)

Caveats about this this method for estimating fuel used for space heating in a typical season:

> best applied to residences and small commercial buildings
> skin-load dominated
> NOT passively solar-heated beyond SSF=10%

(We will examing a similar calculation for passively-solar heated buildings a bit later.)

This week... Designing for Heating and Cooling

MEEB: Calculating Heating-Season Fuel Consumption
(Conventional Buildings)

To begin, we need to know the following:

> The building's heat loss rate (q and q_v);
> The building's internal and solar gain rates;
> The building's balance point temperature;
> How often the outside temperature falls below the building's balance point temperature. (DD)

This week... Designing for Heating and Cooling

MEEB: Calculating Heating-Season Fuel Consumption
(Conventional Buildings)

We know how to find q and q_v ; we know that it is possible to find both internal and solar gain rates. How do we find the **"balance point temperature"?**

Q_i = BALANCE POINT q_{total} ; (Q_i is internal gains + solar gains)

BALANCE POINT $q_{total} = UA_{total} (t_i - t_b)$;

where t_b = balance point temperature

t_i = average interior temperature over 24 hours, during the heating season

and UA_{total} = Total Heat Loss Rate (envelope + infiltr.)

This week... Designing for Heating and Cooling

MEEB: Calculating Heating-Season Fuel Consumption
(Conventional Buildings)

Rewriting that equation to solve for balance point temperature, we see that

$$t_b = t_i - Q_i / UA_{total}$$

But nothing's that easy. Q_i cannot be determined so directly. Usually, the factor for daily total solar gain and internal gains are taken from charts or standard tables, and so themselves may be incorrect and different from actual figures. Furthermore, each month has different solar gains, since insolation is a factor of shading, window design, and the change in solar angle.

This week... Designing for Heating and Cooling

MEEB: Calculating Heating-Season Fuel Consumption
(Conventional Buildings)

See example 8.1, Part G, page 257.

The estimations made are so coarse as to indicate that making these calculations are so complicated that Architects have no business doing them. Nevertheless, the language and concepts are worth understanding so that you can communicate with those experts and specialists you work with to design these systems.

This week... Designing for Heating and Cooling

MEEB: Calculating Heating-Season Fuel Consumption
(Conventional Buildings)

OK, now we know how to find q and q_v; we know that it is possible to find both internal and solar gain rates; and someone has determined the building's "balance point temperature."

And now...

Riddle me this, Batman: **What's a Degree Day?**

This week... Designing for Heating and Cooling

MEEB: Calculating Heating-Season Fuel Consumption
(Conventional Buildings)

A "degree day" value is the sum of the differences, over a period of time, between estimated average daily temperatures and a baseline temperature.

Cooling Degree Days (CDDs) refer to temperatures *above* the baseline temperature; **Heating Degree Days (HDDs)** refer to temperatures *below* that baseline.

The baseline itself is arbitrary, but typically reflects standard values for baseline temperatures, so that more contemporary calculations indicate baseline temperatures of 50 or 55, down from the traditional 65, due to improved envelope insulation.

This week... Designing for Heating and Cooling

MEEB: Calculating Heating-Season Fuel Consumption
(Conventional Buildings)

Yearly Space Heating Energy Consumption:

$$E = \frac{(UA)\ (DD\ \text{balance point})\ (24h)}{(AFUE)\ (V)}$$

E: Units of Fuel consumed per year
UA: total heat loss rate, envelope + infiltration
DD balance point: Degree Day at an indicated balance point temp.
AFUE: Annual Fuel Utilization Efficiency (%) (Table 8.7)
V: Fuel Heating Value (Table 8.5)

See example 8.10.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Performance

Although until now, when discussing solar heating systems, we've assumed that all of them "function," as designers we would like some way of assessing their potential thermal contribution, so that we may choose the most suitable method.

Our reading describes each of the general categories of passive solar systems and illustrates methods for making calculations showing their efficacy.

The systems under consideration are as follows:

> **Glazing Performance**
> May include night-insulation, superwindow assemblies, or transparent insulation materials like aerogel.

> **Direct Gain Systems**
> More mass area will give a more stable performance.

> **Sunspaces**
> Serve the occupied spaces behind, and so may themselves be subject to wide thermal variations.

> **Trombe Walls** Uncommon in the US
> **Water Walls** Even more uncommon in the US

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Performance

> *Load Collector Ratio Annual Performance*

Provides a more time-consuming and detailed method for calculating the monthly SSF and auxiliary energy needs; the proceedure described in MEEB gives annual results.

Step 1 - Choose lcation and reference passive system;
Step 2 - Select (tentative) size for solar openings;
Step 3 - Calculate non-south envelope heat loss;
calculate the BLC (Building Load Coefficient);
Step 4 - Check building's overall loss rate;
Step 5 - Determine the vertical projection of the solar opening;
Step 6 - Find the LCR (Load Collector Ratio);

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Performance

> *Load Collector Ratio Annual Performance*

Step 7 - Based on the LCR, refer to system which matches the design system, consult table, find approximate location, and extract by interpolation the annual SSF.

Step 8 - Find approximate annual auxiliary heating based on remainder heating required after SSF is accounted for.

Step 9 - Compare design guidelines with calculated results. Calibrate the proportions of decreased BLC (better conservation) or choose a more suitable passive system.

Tradeoffs, by which **one accepts less-than-ideal performance in one system in order to improve performance in another**, may be evaluated in this way.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Performance

> *Variations on Reference Systems*

Sensitivity Curves indicate how a particular design might perform as it varies from a particular, standard passive system configuration.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Performance

> *Thermal Lag through Mass Walls*

This refers to the thermal inertia of materials, especially massive materials. Heavy materials, since they are effective in absorbing energy, take longer for their temperature to rise. Subsequently, they take longer to cool. These effects may be useful as the insolation of a space changes from minimum to maximum to minimum throughout the day.

This week... Designing for Heating and Cooling

MEEB: Passive Solar Heating Performance

> *Internal Temperatures*

"Two qualities are of particular interest to passive solar designers: How much higher, compared to the outdoor temperature, will the average indor temperature be from solar heating alone? Also, how widely will this internal temperature vary (swing) on a clear winter day?" p275

This week... Designing for Heating and Cooling

MEEB: Approximate Method for Calculating Heat Gain

Unlike for heat loss (heating loads), heat gain (cooling loads) are more complicated to calclulate.

A legitamate calculation of cooling loads must take into account not just sensible heat (which relates to DB temperature) but also latent heat (which relates to WB temperature).

A simplified heat-gain method has been developed for residential buildings as well as similar small buildings of different uses, based on the following assumptions:

This week... Designing for Heating and Cooling

MEEB: Approximate Method for Calculating Heat Gain

1) The building is occupied and conditioned for 24hr/day.

2) The building derives most of its heat gain via envelope and ventilation, not internal loads.

3) The building and its occupants are tolerant of undersized equipment, which might result in both noticably higher indoor temperatures and greater variations throughout the day.

This week... Designing for Heating and Cooling

MEEB: Approximate Method for Calculating Heat Gain

This method considers each of the following:

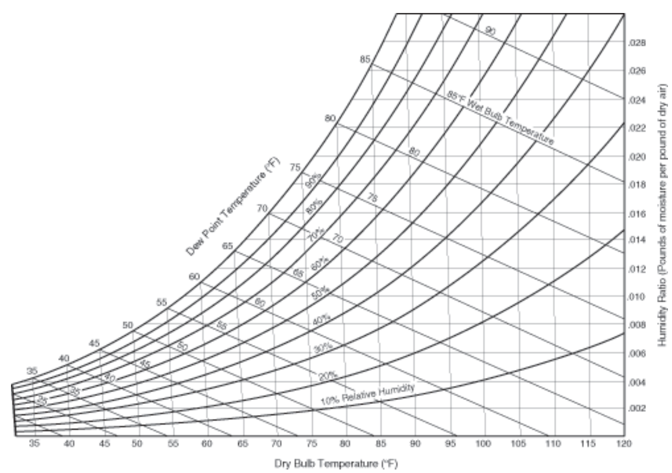
> Gains through Roofs and Walls
> Gains through Glass
> Gains from Outside Air
> Gains from People
> Gains from Lights
> Gains from Equipment
> Latent Heat Gains

See details pp. 277 - 279

This week... Designing for Heating and Cooling

MEEB: Psychrometry

We discussed the “Pyschrometric Chart” back in February, when we talked about the relationship between human comfort and certain properties of our immediate environment, such as temperature (dry-bulb or wet-bulb) and relative humidity.



The “Psychrometric Chart” contrasts DB temperature (horizontal axis) with rh (vertical axis) and relates them to WB temperature.

This week... Designing for Heating and Cooling

MEEB: Psychrometry

Psychrometric charts often include other "iso" lines, which show how certain values change with relation to each other:

> Humidity ratio (horizontal)

> Specific volume (diagonal)

> Enthalpy (points along curve)

What is enthalpy? "Total heat" both sensible and latent.

Evaporative cooling, for instance, lowers temperature and increases humidity *without changing enthalpy.* **Why?**

This week... Designing for Heating and Cooling

MEEB: Psychrometry

Psychrometric charts often include other “iso” lines, which show how certain values change with relation to each other:

> Cooling Processes

> Heating Processes

Let’s turn to pages 284 and 285 to follow the progress of the conditioning over the states described graphically on the Psychrometric Chart.

This week... Designing for Heating and Cooling

MEEB: Detailed Hourly Heat Gain (Cooling) Calcs

> Approximate methods are useful for initial estimates, but greater detail is required to size appropriately (ie, exactly and with attention to economy) overall capacity and peak loads.

ASHREA describes three methods:

Transfer Function Method (TFM)
Total Equivalent Temperature Differential (TETD/TA)
Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF... WXYZ)

This week... Designing for Heating and Cooling

MEEB: Detailed Hourly Heat Gain (Cooling) Calcs

Transfer Function Method (TFM) &
Total Equivalent Temperature Differential (TETD/TA)

These methods provide hourly values for gains/loads, througout the day. *"They account for thermal storage by building mass, which can significantly shift the impact of instantantaneous heat gains on the actual cooling load for the HVAC equipment."* p 286

This is why engineers use computer-based modelling programs!

This week... Designing for Heating and Cooling

MEEB: Detailed Hourly Heat Gain (Cooling) Calcs

Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF)

More direct technique, affording a single, one-hour value. Considerable, experienced judgement needs be used to choose the appropriate hour for suitable analysis.

Otherwise, as we've previously discussed, designers should consider the following items when thinking about cooling systems:

Building envelope characteristics; building location and orientation; outdoor design conditions; indoor design conditions, including DB, WB, and ventilation rate; daily schedule of lighting, occupancy, equipment, and processes which contribute to heat gain; thermal zoning requirements.

This week... Designing for Heating and Cooling

MEEB: Passive Cooling Calculation Proceedures

The passive cooling techniques, discussed earlier in our reading and listed below, often require innovative architectural design to effect their implementation. Quantitative Analysis of their impact is crucial, obvously, to support the choice of one or more of these systems. (See page 287 through 314.)

> *Cross Ventilation*
> *Stack Ventilation*
> *Night Ventilation of Thermal Mass*
> *Fan Assisted Evaporative Cooling*
> *Cool Towers*
> *Roof Pond Cooling*
> *Earth Tubes*
> *Passive Cooling Summary*

Were there items in your reading which particularly interested you?

This week... Designing for Heating and Cooling

Now in Class:

Worksheet #8:
Designing for Heating and Cooling
(Chapter 8.8 > 8.13)

Next week... Welcome to the Real World, Baby!

HVAC Systems for Smaller Buildings

(Chapter 9)