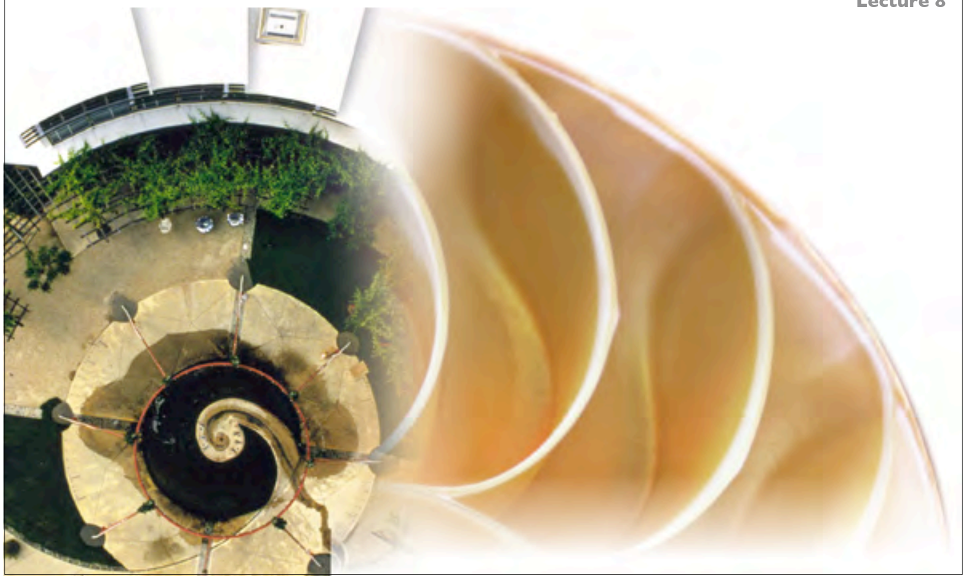
# Whole Building Heat Transfer
## Part 2

ARCH 331/431 Spring 2008
Lecture 8



## announcements 4/24/08

### A3: Envelope Heat Transfer

References: Available by this weekend (course website)

Due next week

**Lecture: Tonight, 6:30 in Kane Hall, Room 210**

Lars GemzØe Architect MAA,Associate Partner, Gehl Architects, Copenhagen, Denmark

*Global Green: A lecture/panel series showcasing Danish and Pacific Northwest Sustainable Planning and Design: "PLACES FOR PUBLIC LIFE:WINNING BACK PUBLIC SPACE AROUND THE WORLD."*

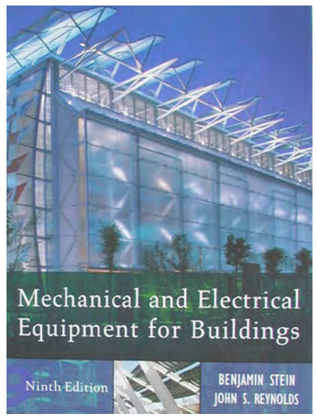

Assigned Readings by Section (not page)

**ON RESERVE**
caup library

**9th Edition**

**Chapter 4**

Thermal Properties of Building and Insulations Materials (beginning on page 147)

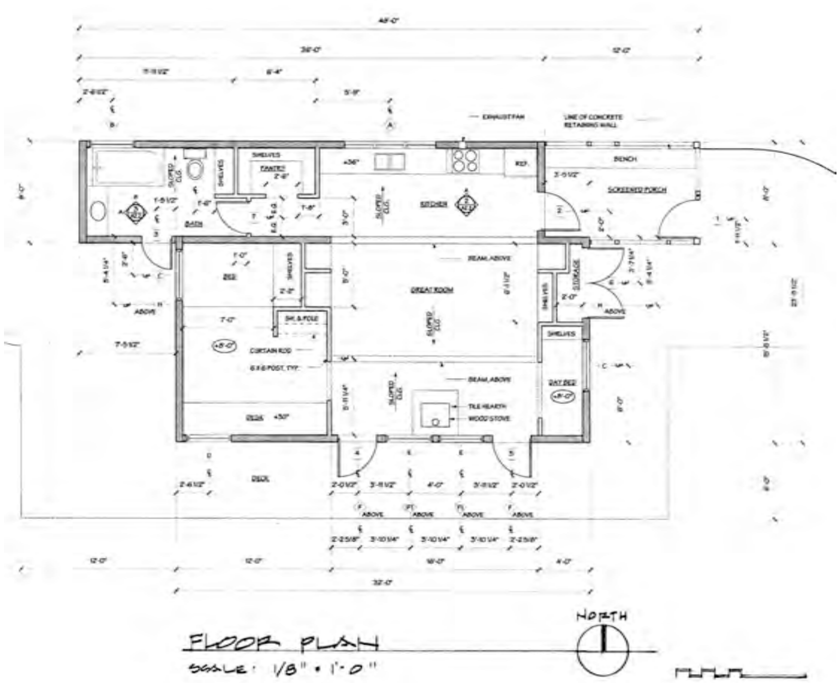



**IN REFERENCE**
caup library

**10th Edition**

**Appendix E**

Thermal Properties of Materials and Assemblies (beginning on page 1547)

**1. ENVELOPE UA**

**U x A**

*BTU/hr $ft^2$ °F x $ft^2$*

**2. INFILTRATION "UA"**

**$VHC_{air}$ x Volume x ACH**

*018 BTU/$ft^3$ °F x $ft^3$ x no./hr*

**3. PERIMETER "UA"**

**F x P**

*(BTU/hr ft °F) x (ft)*

**STEP 1: Envelope Heat Transfer Coefficient (UA conduction)**

| Building Element Orientation | Element | U-value BTU/hr $ft^2$ °F | Area $ft^2$ | U x Area BTU/hr °F | Description |
|---|---|---|---|---|---|
| South | Door C | | | | |
| | Window D | | | | |
| | Door 4 | | | | |
| | Windows E (2) | | | | |
| | Door 5 | | | | |
| | Walls | | | | |
| | | | | | |
| East | Window C | | | | |
| | Doors 6 | | | | |
| | Door 2 | | | | |
| | Walls | | | | |
| | | | | | |
| North | Windows A (3) | | | | |
| | Window B | | | | |
| | 7 Window | | | | |
| | 8 Window | | | | |
| | 3 Door | | | | |
| | Walls | | | | |
| | | | | | |
| | | | | | |
| West | Window C | | | | |
| | | | | | |
| | | | | | |
| | Ceiling/Roof | | | | |
| | | | | | |
| | | | UA conduction | | |

**STEP 2: Infiltration Heat Loss ("UA" infiltration)**

| | | |
|---|---|---|
| Volumetric Heat Capacity (Air) | 0.0 | BTU/$ft^3$ °F |
| Building Volume ($ft^3$) | | $ft^3$ |
| Air Changes per Hour (ACH) | | ACH |
| "UA" infiltration = VHC x Volume x ACH | 0.0 | BTU/hr °F |

**STEP 3: Perimeter Heat Loss ("UA" perimeter)**

| | | |
|---|---|---|
| Heat loss coefficient (F) | | BTU/hr °F ft |
| Length of building perimeter (P) | | $ft^3$ |
| "UA" perimeter = F x P | 0.0 | BTU/hr °F |

## Determining UA

**Step 1: The Building Envelope** (conductive heat transfer)

$$Q = UA_{envelope} \times \Delta T$$

Q = Heat loss or gain (Btu/h)

U = conductance (Btu/h sf °F)

A = area (sf)

$\Delta T = T_{outside} - T_{inside}$ (°F)

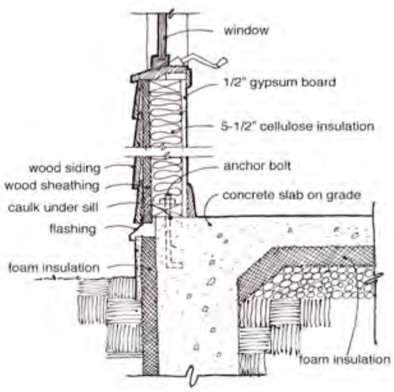
**U ~ C (conductance)**

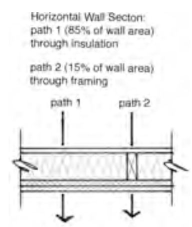
**C = 1/R (resistance)**

*Finding UA is a process of finding the R-values of each layer of the building envelope*

**SERIES HEAT TRANSFER**

| | k conductivity BTU - in / hr ft² °F | C Conductance BTU / hr ft² °F | R Resistance hr ft² °F / BTU | Path 1 (insulation) hr ft² °F / BTU | Path 2 (framing) hr ft² °F / BTU |
|---|---|---|---|---|---|
| outside air film | | | | | |
| 1/2" wood siding | | 1.24 | | | |
| 1/2" medium density particleboard | | | | | |
| 5-1/2" fiberglass batt insulation | | | | | |
| 5-1/2" wood framing (Douglas Fir) | | | | | |
| 1/2" gypsum board | | | | | |
| Inside Air Film | | | | | |
| | | | R total | | |
| | | | | x 85% | x 15% |
| | | | Paths 1 & 2 | | |
| | | | Overall R-value of Walls & Ceiling | | |
| | | | Overall U-value of Walls & Ceiling | | |




**PARALLEL HEAT TRANSFER**

**STEP 1: Envelope Heat Transfer Coefficient (UA conduction)**

| Building Element: Orientation | Building Element: Element | U-value BTU/hr ft² °F | Area ft² | U x Area BTU/hr °F | Description |
|---|---|---|---|---|---|
| South | Door C | | | | |
| | Window D | | | | |
| | Door 4 | | | | |
| | Windows E (2) | | | | |
| | Door 5 | | | | |
| | Walls | | | | |
| | | | | | |
| East | Window C | | | | |
| | Doors 6 | | | | |
| | Door 2 | | | | |
| | Walls | | | | |
| | | | | | |
| North | Windows A (3) | | | | |
| | Window B | | | | |
| | 7 Window | | | | |
| | 8 Window | | | | |
| | 3 Door | | | | |
| | Walls | | | | |
| | | | | | |
| | | | | | |
| West | Window C | | | | |
| | | | | | |
| | | | | | |
| | Ceiling/Roof | | | | |
| | | | | | |
| | | | UA conduction | | |

## Determining UA

**Step 2: Infiltration** (convective heat transfer)

$$Q = .018 \times V_{air} \times ACH \times \Delta T$$

Q = heat loss or gain

.018 = volumetric heat capacity of air (BTU/ft$^3$ °F)

ACH = air changes per hour

$V_{air}$ = volume of air (ft$^3$)

$\Delta T$ = $T_{inside} - T_{outside}$

**STEP 2: Infiltration Heat Loss ("UA" infiltration)**

| | | |
|---|---|---|
| Volumetric Heat Capacity (Air) | 0.018 | BTU/ft$^3$ °F |
| Building Volume (ft$^3$) | 9216 | ft$^3$ |
| Air Changes per Hour (ACH) | 1.30 | ACH |
| **"UA" infiltration** = VHC x Volume x ACH | **216** | BTU/hr °F |

**Farnsworth House**
**$UA_{ref}$**

**Farnsworth House Heat Transfer Coefficient (UA conduction)**

| Building Element Orientation | Element | U-value BTU/hr ft² °F | Area ft² | U x Area BTU/hr °F | Description |
|---|---|---|---|---|---|
| South | Walls, Doors and Windows | 1.124 | 384 | 432 | |
| | | | | 0 | |
| East | Walls, Doors and Windows | 1.124 | 192 | 216 | |
| | | | | 0 | |
| North | Walls, Doors and Windows | 1.124 | 384 | 432 | |
| | | | | 0 | |
| West | Walls, Doors and Windows | 1.124 | 192 | 216 | |
| | | | | 0 | |
| Ceiling/Roof | | 0.158 | 1152 | 182 | |
| | | | | 0 | |
| Floor | | 0.112 | 1152 | 129 | |
| | | | | 0 | |
| | | | UA conduction = | 1606 | BTU/hr °F |

**STEP 2: Infiltration Heat Loss ("UA" infiltration)**

| | | |
|---|---|---|
| Volumetric Heat Capacity (Air) | 0.018 | BTU/ft³ °F |
| Building Volume (ft³) | 9216 | ft³ |
| Air Changes per Hour (ACH) | 1.30 | ACH |
| **"UA" infiltration** = VHC x Volume x ACH | 216 | BTU/hr °F |

**Note:**
*Step 3, "UA"$_{perimeter}$ is not applicable since the Farnsworth House is not built with the floor in contact with the earth.*

**STEP 3: Perimeter Heat Loss ("UA" perimeter)**

| | | |
|---|---|---|
| Heat loss coefficient (F) | na | BTU/hr °F ft |
| Length of building perimeter (P) | na | ft³ |
| **"UA" perimeter** = F x P | na | BTU/hr °F |

**$UA_{reference}$** 1822 BTU/hr °F

*If the Farnsworth House was built with a slab-on-grade or a basement condition, the* ***Perimeter Heat Loss*** *would have to be considered (Step 3) as follows:*

## Step 3: Perimeter

*for slab-on-grade or basement conditions - not applicable to the Farnsworth House*

$$Q = F \times P \times \Delta T$$

F = empirically derived constant (Table E.11, pg. 1582)

P = length of perimeter (ft)

$\Delta T = T_{inside} - T_{outside}$

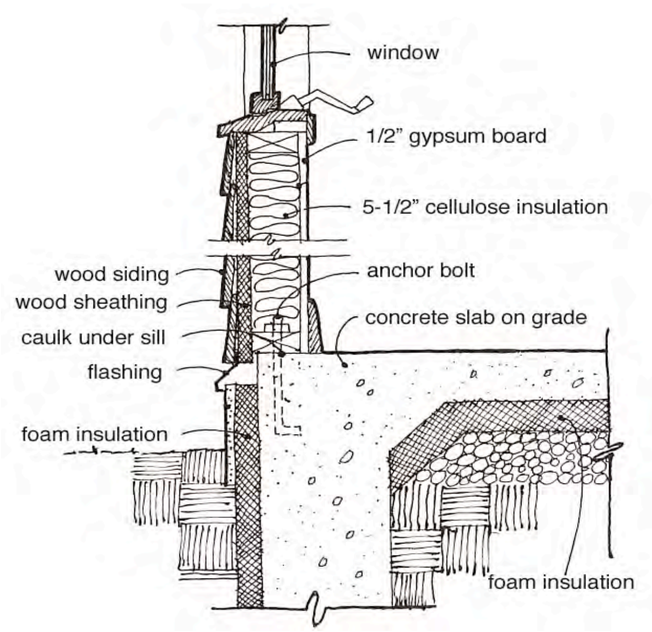



Table E.12

**TABLE E.12 Heat Flow Coefficients ($F_2$) for Slab-on-Grade Floors with Various Insulation Strategies**

| | $F_2$ | |
|---|---|---|
| R-Value, Position, and Width (or Depth) of Insulation | (Btu/h ft °F) | (W/m K) |
| Uninsulated slab | 0.73 | *1.26* |
| R-5 (SI: R-0.88) Horizontal insulation, 2 ft (0.6 m), no thermal break | 0.70 | *1.21* |
| R-10 (SI: R-1.76) Horizontal insulation, 2 ft (0.6 m), no thermal break | 0.70 | *1.21* |
| R-15 (SI: R-2.64) Horizontal insulation, 2 ft (0.6 m), no thermal break | 0.69 | *1.19* |
| R-5 (SI: R-0.88) Horizontal insulation, 4 ft (1.2 m), no thermal break | 0.67 | *1.16* |
| R-10 (SI: R-1.76) Horizontal insulation, 4 ft (1.2 m), no thermal break | 0.64 | *1.11* |
| R-15 (SI: R-2.64) Horizontal insulation, 4 ft (1.2 m), no thermal break | 0.63 | *1.09* |
| R-5 (SI: R-0.88) Vertical insulation, 2 ft (0.6 m) | 0.58 | *1.00* |
| R-10 (SI: R-1.76) Vertical insulation, 2 ft (0.6 m) | 0.54 | *0.93* |
| R-15 (SI: R-2.64) Vertical insulation, 2 ft (0.6 m) | 0.52 | *0.90* |
| R-5 (SI: R-0.88) Vertical insulation, 4 ft (1.2 m) | 0.54 | *0.93* |
| R-10 (SI: R-1.76) Vertical insulation, 4 ft (1.2 m) | 0.48 | *0.83* |
| R-15 (SI: R-2.65) Vertical insulation, 4 ft (1.2 m) | 0.45 | *0.78* |
| R-10 (SI: R-1.76) Fully insulated slab (insulated under entire slab as well as around edge) | 0.36 | *0.62* |

*Source: Super Good Cents Heat Loss Reference, Vol. 1,* Ecotope Group, for Bonneville Power Administration, 1988.
Insulation is extruded polystyrene, R = 5.0 h ft² °F/Btu-in. (SI: R = 34.7 m K/W).
Soil conductivity is 0.75 Btu/h ft °F (1.30 W/K m).
No thermal break at edge of slab, where so indicated. If a thermal break is provided with horizontal insulation, use the corresponding value for vertical insulation.
Values assume an unheated slab (as per data in Table A-16 of ANSI/ASHRAE/IESNA Standard 90.1-2001, *Energy Standard for Buildings Except Low-Rise Residential Buildings*); $F_2$ values increase substantially when slab is heated.

## Table E.11

**TABLE E.11 Heat Loss Coefficients ($F_2$) for Slab-on-Grade Floors**

| | | *Btu/h °F ft Perimeter Degree Days (65°F base)* | | | *W/K m Perimeter Degree Days (18°C base)* | | |
|---|---|---|---|---|---|---|---|
| Construction[a] | Insulation | 2950 | 5350 | 7433 | 1640 | 2970 | 4130 |
| (a) Block wall, 8 in. (200 mm), brick facing | Uninsulated | 0.62 | 0.68 | 0.72 | 1.07 | 1.17 | 1.24 |
| | Insulated from edge to footer: R-5.4 h ft² °F/Btu (SI: R-0.95 m² K/W) | 0.48 | 0.50 | 0.56 | 0.83 | 0.86 | 0.97 |
| (b) Block wall, 4 in. (100 mm), brick facing | Uninsulated | 0.80 | 0.84 | 0.93 | 1.38 | 1.45 | 1.61 |
| | Insulated from edge to footer: R-5.4 h ft² °F/Btu (SI: R-0.95 m² K/W) | 0.47 | 0.49 | 0.54 | 0.81 | 0.85 | 0.93 |
| (c) Metal stud wall, stucco | Uninsulated | 1.15 | 1.20 | 1.34 | 1.99 | 2.07 | 2.32 |
| | Insulated from edge to footer: R-5.4 h ft² °F/Btu (SI: R-0.95 m² K/W) | 0.51 | 0.53 | 0.58 | 0.88 | 0.92 | 1.00 |
| (d) Poured concrete wall with duct near perimeter[b] | Uninsulated | 1.84 | 2.12 | 2.73 | 3.18 | 3.67 | 4.72 |
| | Insulated from edge to footer, and 3 ft. [910 mm] under floor slab R-5.4 h ft² °F/Btu (SI: R-0.95 m² K/W) | 0.64 | 0.72 | 0.90 | 1.11 | 1.24 | 1.56 |

*Source:* Reprinted with permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. from 2001 *ASHRAE Handbook—Fundamentals*. The SI units for $F_2$ shown in the last three columns were appended to the ASHRAE I-P data by the authors.

[a] See Fig. E.1 for illustrations of the listed constructions.

[b] Weighted average temperature of heating duct was assumed to be 110°F (43°C) during the heating season (outdoor air temperature less than 65°F [18°C]).

*Note:* To use this table:

$$q = F_2 P \Delta t$$

where

$q$ = heat loss through perimeter (Btu/h or W)

$F_2$ = heat loss coefficients from above

$P$ = perimeter of exposed slab edge (ft or m)

$\Delta t$ = temperature difference between indoor and outdoor air (°F or °C).

Do not assume additional losses from the slab to the earth below. Heat gains are assumed to be nonexistent.

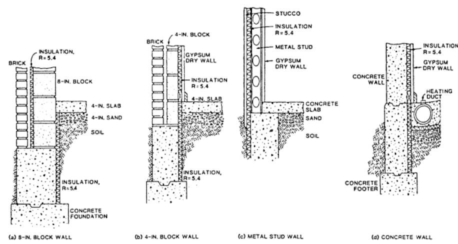
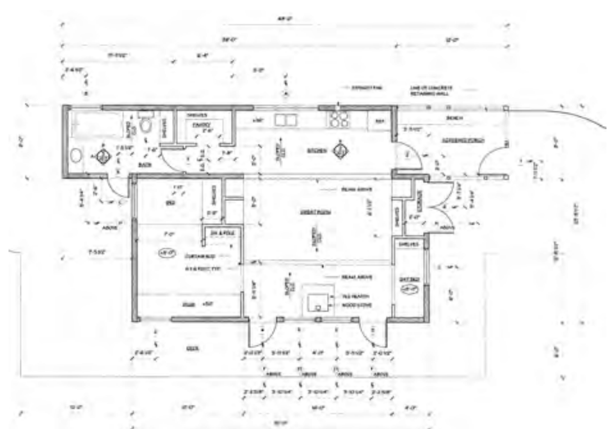



***Fig. E.1*** *Insulation and construction configurations for Table E.11 data (heat loss coefficients for slab-on-grade floors). Reprinted with permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. from 2001* ASHRAE Handbook—Fundamentals.



**STEP 3: Perimeter Heat Loss ("UA" perimeter)**

| | | |
|---|---|---|
| Heat loss coefficient (F) | 0.36 | BTU/hr °F ft |
| Length of building perimeter (P) | 127.0 | ft³ |
| **"UA" perimeter** = F x P | 46 | BTU/hr °F |

## Farnsworth House
## $UA_{ref}$

**Farnsworth House Heat Transfer Coefficient (UA conduction)**

| Building Element Orientation | Element | U-value BTU/hr ft$^2$ °F | Area ft$^2$ | U x Area BTU/hr °F | Description |
|---|---|---|---|---|---|
| South | Walls, Doors and Windows | 1.124 | 384 | 432 | |
| | | | | 0 | |
| East | Walls, Doors and Windows | 1.124 | 192 | 216 | |
| | | | | 0 | |
| North | Walls, Doors and Windows | 1.124 | 384 | 432 | |
| | | | | 0 | |
| West | Walls, Doors and Windows | 1.124 | 192 | 216 | |
| | | | | 0 | |
| Ceiling/Roof | | 0.158 | 1152 | 182 | |
| | | | | 0 | |
| Floor | | 0.112 | 1152 | 129 | |
| | | | | 0 | |
| | | | **UA conduction =** | 1606 | BTU/hr °F |

**STEP 2: Infiltration Heat Loss ("UA" infiltration)**

| | | |
|---|---|---|
| Volumetric Heat Capacity (Air) | 0.018 | BTU/ft$^3$ °F |
| Building Volume (ft$^3$) | 9216 | ft$^3$ |
| Air Changes per Hour (ACH) | 1.30 | ACH |

**"UA" infiltration** = VHC x Volume x ACH: 216 BTU/hr °F

$UA_{reference}$: 1822 BTU/hr °F

## Winter Hourly Heat Loss

*Predicting Building Heat Loss Under Worst Case (Winter Design) Conditions:*

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

$$\text{Rate of Fuel Use} = \frac{UA_{ref} \times \Delta T}{V \times \text{Efficiency}}$$

| Fuel | Heating Value (V) | Typical Efficiency (%) |
|---|---|---|
| No. 2 oil: | 141,000 BTU/gal | 75 |
| Natural Gas | 1,050 BTU/ft$^3$ | 75 |
| Propane | 2,500 BTU/ft$^3$ | 75 |
| Electricity | 3413 BTU/kW | 100 |

## Winter Hourly Heat Loss

*Predicting Building Heat Loss Under Worst Case (Winter Design) Conditions:*

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

Furnace (heating plant capacity) Sizing:

$Q_{losses} = UA_{ref} \times \Delta T = 1822$ BTU/hr °F x (68° - (-4°))
$Q_{losses} =$ **131,184 BTU/hr**

Rate of Fuel Consumption:

Rate of Fuel Use = 131,184 BTU/hr / (1050 BTU/$ft^3$ x .75)
Rate of Fuel Use = **167 $ft^3$/hr** (natural gas)

## Seasonal Heating Calculations

*Predicting Annual Purchased Heating*

$$E = \frac{(UA)\ (DegreeDays)\ (24\ hr)}{(AFUE)\ \ (V)}$$

*Some Typical Values for Annual Fuel Utilization Efficiency:*

| Type of Furnace | AFUE |
|---|---|
| Natural Gas, natural-draft w/standing pilot | 64.5% |
| Natural Gas, fan-assisted combustion | 80.0% |
| Oil, standard w/improved heat transfer | 76.0% |

## Seasonal Heating Calculations

*Predicting Annual Purchased Heating*

$$E = \frac{(1822\ \text{BTU/hr °F})\ (6013\ \text{°F days})\ (24\ \text{hrs/day})}{(.80)\ (1{,}050\ \text{BTU/ft}^3)}$$

E = **313,020 ft³** natural gas per year

## Farnsworth House

## $UA_{ref}$

## AS BUILT

**Farnsworth House Heat Transfer Coefficient (UA conduction)**

| Building Element: Orientation | Building Element: Element | U-value BTU/hr ft² °F | Area ft² | U x Area BTU/hr °F | Description |
|---|---|---|---|---|---|
| South | Walls, Doors and Windows | 1.124 | 384 | 432 | |
| | | | | 0 | |
| East | Walls, Doors and Windows | 1.124 | 192 | 216 | |
| | | | | 0 | |
| North | Walls, Doors and Windows | 1.124 | 384 | 432 | |
| | | | | 0 | |
| West | Walls, Doors and Windows | 1.124 | 192 | 216 | |
| | | | | 0 | |
| Ceiling/Roof | | 0.158 | 1152 | 182 | |
| | | | | 0 | |
| Floor | | 0.112 | 1152 | 129 | |
| | | | | 0 | |
| | | | **UA conduction =** | **1606** | BTU/hr °F |

**STEP 2: Infiltration Heat Loss ("UA" infiltration)**

| | | |
|---|---|---|
| Volumetric Heat Capacity (Air) | 0.018 | BTU/ft³ °F |
| Building Volume (ft³) | 9216 | ft³ |
| Air Changes per Hour (ACH) | 1.30 | ACH |

**"UA" infiltration** = VHC x Volume x ACH: **216** BTU/hr °F

**$UA_{reference}$**: **1822** BTU/hr °F

## Farnsworth House $UA_{ref}$

**AFTER RENOVATIONS**

**Farnsworth House Heat Transfer Coefficient (UA conduction)**

| Building Element: Orientation | Building Element: Element | U-value BTU/hr ft² °F | Area ft² | U x Area BTU/hr °F | Description |
|---|---|---|---|---|---|
| South | Walls, Doors and Windows | 0.038 | 384 | 15 | |
| | | | | 0 | |
| East | Walls, Doors and Windows | 0.038 | 192 | 7 | |
| | | | | 0 | |
| North | Walls, Doors and Windows | 0.038 | 384 | 15 | |
| | | | | 0 | |
| West | Walls, Doors and Windows | 0.038 | 192 | 7 | |
| | | | | 0 | |
| Ceiling/Roof | | 0.158 | 1152 | 182 | |
| | | | | 0 | |
| Floor | | 0.112 | 1152 | 129 | |
| | | | | 0 | |
| | | | UA conduction = | 355 | BTU/hr °F |

**STEP 2: Infiltration Heat Loss ("UA" infiltration)**

| | | |
|---|---|---|
| Volumetric Heat Capacity (Air) | 0.018 | BTU/ft³ °F |
| Building Volume (ft³) | 9216 | ft³ |
| Air Changes per Hour (ACH) | 0.51 | ACH |

**"UA" infiltration** = VHC x Volume x ACH = **85** BTU/hr °F

**$UA_{reference}$** **439** BTU/hr °F

**439 BTU/hr °F**
**vs.**
**1822 BTU/hr °F**

**76% improvement**

## 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:*

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

## Determine Internal Loads

**PEOPLE** • LIGHTS • **EQUIPMENT**

ENVELOPE • INFILTRATION

### F.3 ESTIMATING SUMMER HEAT GAINS **MEEB 10th, pg. 1610**

**TABLE F.3 Approximate Summer Heat Gains from Occupants, Equipment, Lighting, and Envelope**

Part A. Internal Heat Sources—People and Equipment

| | Area per Person[a] | | Sensible Heat Gain (Btu/h ft² of Floor Area) | | | Sensible Heat Gain (W/m² of Floor Area) | | |
|---|---|---|---|---|---|---|---|---|
| Function | ft² | m² | People[b] | Equipment[c] | Total | People[b] | Equipment[c] | Total |
| Office, U.S.[c] | 180–100 | 16.7–9.3 | 1.3–2.3 | 0.4–1.1 | 1.7–3.4 | 4.1–7.3 | 1.2–3.4 | 5.3–10.7 |
| Office, Europe[d] | | | 1–1.6 | 2.2–4.2 | 3.2–5.8 | 3–5 | 7–13.1 | 10–18.1 |
| School: elementary, U.S. | 100–20 | 9.3–1.9 | 2.3–11.5 | 0–0.6 | 2.3–12.1 | 7.3–36.3 | 0–2.0 | 7.3–38.3 |
| Schools, Europe[d] | | | 3.8–8.0 | 0–0.6 | 3.8–8.6 | 12–25.2 | 0–2.0 | 12.0–27.2 |
| School: secondary, college | 150–100 | 13.9–9.3 | 1.7–2.6 | 0–0.6 | 1.7–3.2 | 5.4–8.2 | 0–2.0 | 5.4–10.2 |
| Health care | | | | | | | | |
| Sleeping (hospital) | 240 | 22.3 | 0.9 | 0.6[e] | 1.5 | 2.8 | 2.0[e] | 4.8 |
| In-patient (clinic) | 120 | 11.1 | 1.9 | Varies | 1.9+ | 6.0 | Varies | 6.0+ |
| Assembly: fixed seats | 15 | 1.4 | 14.0 | — | 14.0 | 44.2 | — | 44.2 |
| standing space, concentrated use | 15–7 | 1.4–0.7 | 21.0–45.0 | 0–0.5 | 21.0–45.5 | 66.3–142.0 | 0–1.6 | 66.3–143.6 |
| Restaurant:[f] | | | | | | | | |
| Fast food: dining area | 15 | 1.4 | 17 | 3.4 | 20.4 | 53.6 | 10.7 | 64.3 |
| Kitchen, refrigeration | | | | 17.1 | 17.1 | | 54.0 | 54.0 |
| Sit-down: dining area | 25 | 2.3 | 10.2 | 5.1 | 15.3 | 32.2 | 16.1 | 48.3 |
| Kitchen, refrigeration | | | | 7.2 | 7.2 | | 22.7 | 22.7 |
| Mercantile: street floor | 50–30 | 4.7–2.8 | 6.3–10.5 | 3.4 | 9.7–13.9 | 19.9–33.1 | 10.7 | 30.6–43.8 |
| Other sales floors | 60–50 | 5.6–4.7 | 5.3–6.3 | 3.4 | 8.7–9.7 | 16.7–19.9 | 10.7 | 27.4–30.6 |
| Shopping center, Europe[d] | | | 3.2 | 0.3–1.3 | 3.5–4.5 | 10 | 1.0–4.0 | 11.0–14.0 |
| Warehouse | 1000–300 | 92.9–27.9 | 0.4–1.2 | — | 0.4–1.2 | 1.3–3.8 | — | 1.3–3.8 |
| Hotels, nursing homes | 300–200 | 27.9–18.6 | 0.8–1.2 | 3.4 | 4.2–4.6 | 2.5–3.8 | 10.7 | 13.2–14.5 |
| Apartments[g] | 300–200 | 27.9–18.6 | 0.8–1.2 | See note g | See note g | 2.5–3.8 | See note g | See note g |

## Determine Interal Loads

PEOPLE • **LIGHTS** • EQUIPMENT

ENVELOPE • INFILTRATION

**MEEB 10th, pg. 1610**

Part B. Internal Heat Sources—Electric Lighting

| | Sensible Heat Gain[h] (Btu/h ft² of Floor Area) | | | Sensible Heat Gain[h] (W/m² of Floor Area) | | |
|---|---|---|---|---|---|---|
| Function | DF<1 | 1<DF<4[h] | DF>4[h] | DF<1 | 1<DF<4[h] | DF>4[h] |
| Office | 5.1 | 2.0 | 0.5 | 16.1 | 6.3 | 1.6 |
| School: elementary | 6.3–6.8 | 2.5–2.7 | 0.6–0.7 | 19.9–21.5 | 7.9–8.5 | 1.9–2.2 |
| School: secondary, college | 6.3–6.8 | 2.5–2.7 | 0.6–0.7 | 19.9–21.5 | 7.9–8.5 | 1.9–2.2 |
| Health care | | | | | | |
| Sleeping (hospital) | 6.8 | 2.7 | 0.7 | 21.5 | 8.5 | 2.2 |
| In-patient (clinic) | 6.8 | 2.7 | 0.7 | 21.5 | 8.5 | 2.2 |
| Assembly | 3.8 | 1.5 | 0.4 | 12.0 | 4.7 | 1.3 |
| Restaurants[f] | 6.3 | 2.5 | 0.6 | 19.9 | 7.9 | 1.9 |
| Mercantile | 5.1–6.8 | 2.0–2.7 | 0.5–0.7 | 16.1–21.5 | 6.3–8.5 | 1.6–2.2 |
| Warehouse | 2.4 | 1.0 | 0.2 | 7.6 | 3.2 | 0.6 |
| Hotels, nursing homes | 6.8 | 2.7 | 0.7 | 21.5 | 8.5 | 2.2 |
| Apartments[g] | Up to 6.8 | Up to 2.7 | Up to 0.7 | Up to 21.5 | Up to 8.5 | Up to 2.2 |