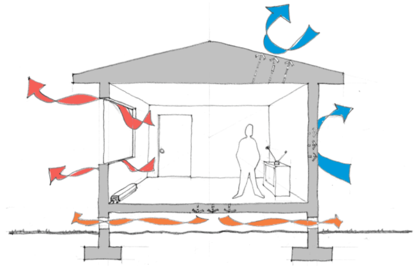


ARCHITECTURE 331/431

Environmental Control Systems

A3: Envelope Heat Transfer

OBJECTIVES

To understand and apply the concepts of conductive and infiltrative heat transfer, including parallel and series heat transfer through a wood-frame wall assembly, to determine the overall heat loss coefficient for a small house.

METHODOLOGY

The Building Heat Loss Coefficient (UA_{ref}) is found by identifying every route of heat loss from a building and adding these together. The routes for heat transfer between the interior and exterior are through the **building envelope**, air exchange between inside and outside (**infiltration**) and sometimes through the ground (**perimeter**), depending on how the building meets the ground.

For the small house in the attached drawings, determine the overall heat transfer coefficient (UA reference). Use the attached charts to organize your area and wall assembly take-offs. Use the tables that will be provided (PDF) on the course website (or in MEEB 9th ed., Chapter 4; MEEB 10th ed., Appendix E) to determine the R-values and for materials and the U-values for all assemblies of the building envelope. To estimate the infiltration heat losses, choose a location for this house in coordination with your discussion section instructor.

1. ENVELOPE:

The conductive heat transfer through all elements of the building envelope that experience a ΔT from one side to the other: walls, floor, roof, windows, doors, etc., is given by the following relationship:

$$\mathbf{UA} = \mathbf{U} \times \mathbf{A}$$

$$(\text{BTU/hr ft}^2\ {}^{\circ}\text{F}) \times (\text{ft}^2)$$

Find the U-value for each element of the building envelope, multiply by the area of that element, then add the UA values for each element to arrive at the overall UA for the building envelope (parallel heat transfer). The U-values for the roof, windows and doors can be found directly from tables in MEEB 9th (Chapter 4) or MEEB 10^{th} (Appendix E). These will also be made available on the course website as PDF documents. The U-value for the exterior walls must be determined by a process of finding the R-values for each material in the wall's assembly (series heat transfer).

Wall areas can by found by taking measurements from the building plan which is drawn at approximately 1/8" = 1'-0", and subtracting the areas of doors and windows. The interior walls are nominally **9'-0" tall** (floor to ceiling).

Windows

Use the following window schedule to determine the area of all the windows in the house. Windows are indicated on the plans with a **letter** in a **square** adjacent to each door. The doors are **double-glazed, clear, wood** windows (Table E.14).

Window	Dimensions	Area (ft^2)
A	2'-0" x 4'-0"	8
B	3'-0" x 4'-0"	12
C	3'-6" x 3'-6"	12.25
D	3'-0" x 3'-0"	9
E	3'-0" x 5'-0"	15

Doors

Use the following door schedule to determine the area for all the doors in the house. Doors are indicated on the plans with a **number** in a diamond adjacent to each window. The doors are wood (or wood slab in wood frame), some with glazing and others unglazed (MEEB 10, Table E.10).

Door	Dimensions	Area (ft²)	Description
1	3'-0" x 6'-8"	20	Screen Door (not applicable)
2	3'-0" x 6'-8"	20	Glazed Door, 25% glazing
3	2'-4" x 6'-8"	15.56	Glazed Door, 6% glazing
4	3'-0" x 6'-8"	20	Glazed Door, 45% glazing
5	3'-0" x 6'-8"	20	Glazed Door, 45% glazing
6	2'-8" x 6'-8"	17.78	Unglazed Door, 1-3/8" solid core flush

Roof

This building has a flat, built-up roof with a plywood deck, 2" x 8" rafters @ 24" O.C. and R—19 blanket insulation with non-reflective air space, gypsum board, and acoustic tile. The ceiling height is nominally 9'-0". You may also discuss with your section instructor the option of creating your own roof resolution for this house.

Walls

Use the illustration and table on the following page to determine the U-value for the wall. Framing consists of 2" x 6" studs at 16" o.c. resulting in 15% of the wall area having framing and 85% of the wall area having insulation. Use MEEB 10, Table E.1 to find the R-values for each element. For some materials you may have to first find the conductance (C) or the conductivity (k) and convert this value to an R-value.

2. INFILTRATION:

Infiltration is the exchange through leaks, cracks, ventilation. This represents a loss of energy through the replacement of conditioned interior air with (colder) outside air.

"UA" = VHC_{air} x Volume x ACH

(.018 BTU/ft^3 °F) x (ft^3) x (no./hr)

Estimate the volume of enclosed space in this house (9'-0" ceilings or your own design), then estimate the overall infiltration rate (ACH) using Table E.27 (MEEB 10). Construction is "tight"; design for "winter" conditions, using climate information from Appendix B.

3. PERIMETER:

Perimeter heat transfer is applicable to this house which has direct contact with the ground via a slab-on-grade. The "UA" is a function of the length of the building's perimeter (ft) and an empirically derived constant found by referring to Tables E.11, E.12 or E.13:

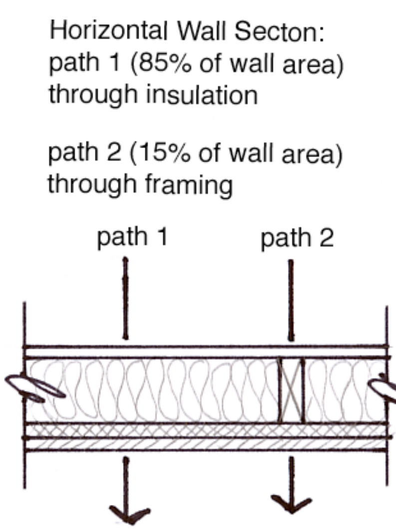
"UA" = F x P

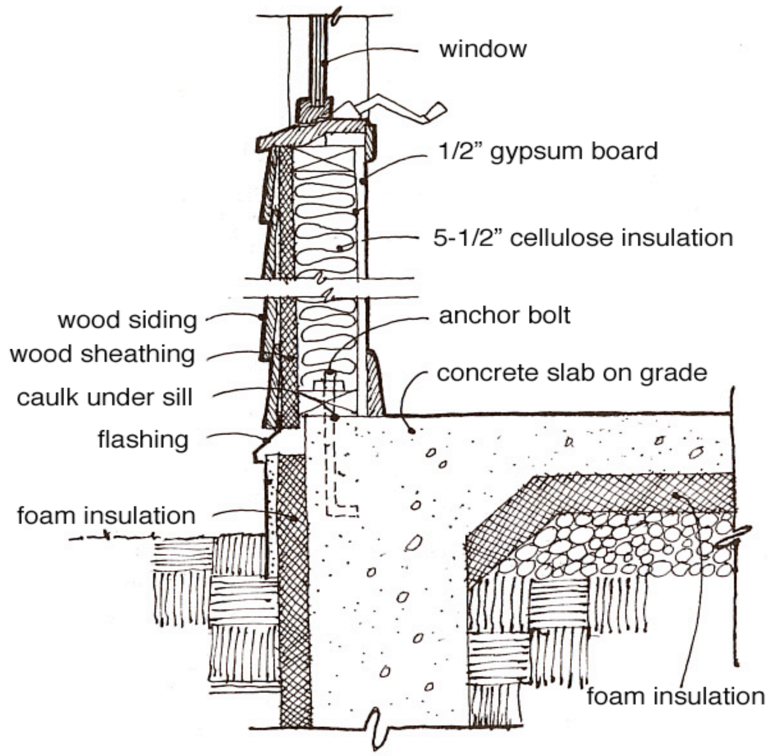
(BTU/hr ft °F) x (ft)

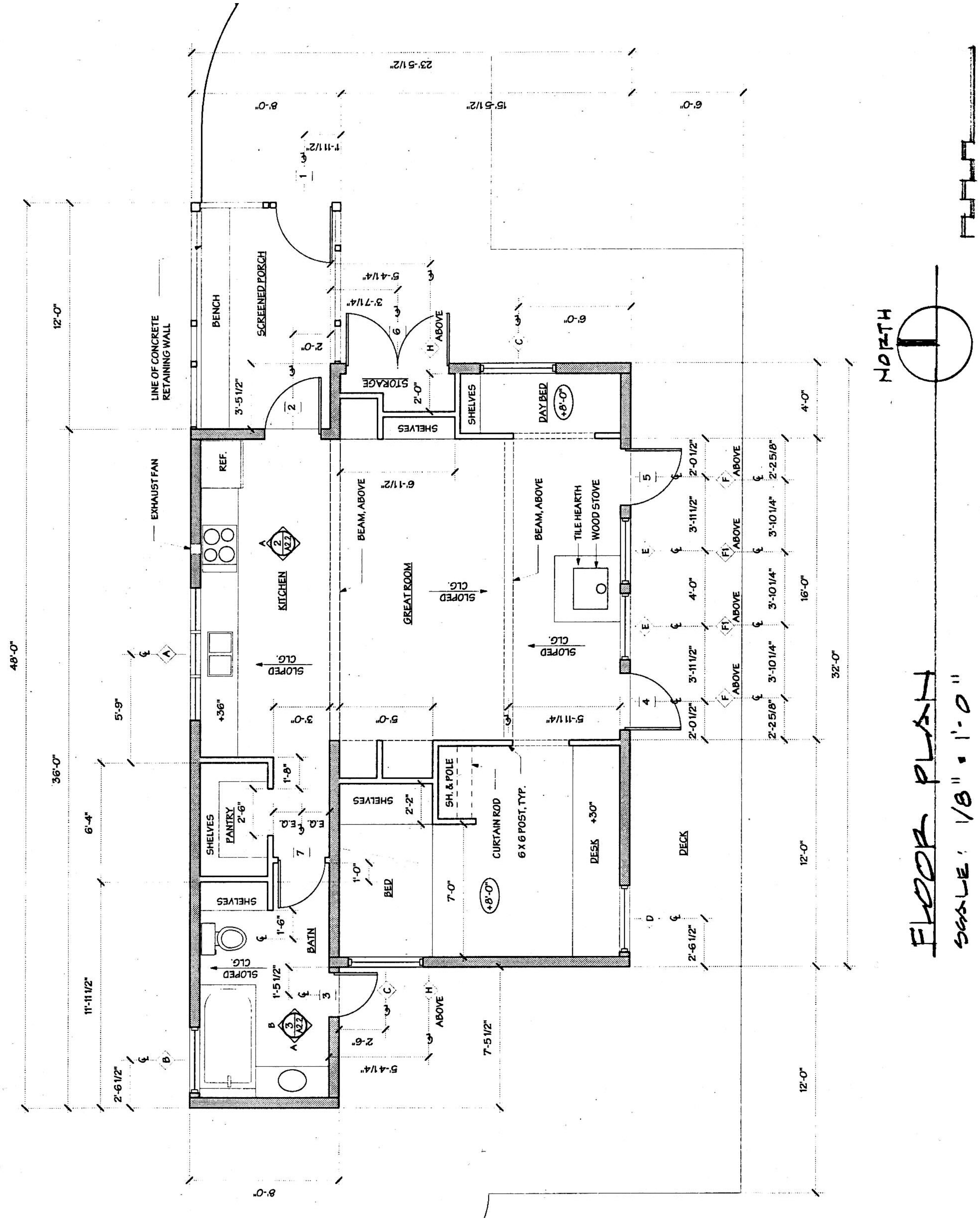
This is an R-10 fully insulated slab, insulated under the entire slab as well as around the edge, as illustrated on the next page.

Typical Wall Construction

	k conductivity $\frac{\text{BTU - in}}{\text{hr ft}^2\ °\text{F}}$	C Conductance $\frac{\text{BTU}}{\text{hr ft}^2\ °\text{F}}$	R Resistance $\frac{\text{hr ft}^2\ °\text{F}}{\text{BTU}}$	Path 1 (insulation) $\frac{\text{hr ft}^2\ °\text{F}}{\text{BTU}}$	Path 2 (framing) $\frac{\text{hr ft}^2\ °\text{F}}{\text{BTU}}$
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		






FLOOR PLAN
SCALE: 1/8" = 1'-0"
NORTH
KITCHEN
GREAT ROOM
SCREENED PORCH
STORAGE
PANTRY
BATH
BED
DAY BED
DESK
DECK
BENCH
SHELVES
REF.
EXHAUST FAN
TILE HEARTH
WOOD STOVE
BEAM, ABOVE
SLOPED CLG.
CURTAIN ROD
6 X 6 POST, TYP.
SH. & POLE
LINE OF CONCRETE RETAINING WALL
48'-0"
36'-0"
32'-0"
23'-5 1/2"
15'-5 1/2"
16'-0"
12'-0"
8'-0"
6'-0"

Predicting Building Heat Transfer

UNDER STEADY STATE CONDITIONS:

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

or

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

Q_{gains} = people, lights equipment, furnace, sun

Q_{losses} = heat loss due to:

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

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

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

Building Element		Load Coefficient	Actual Formula
ENVELOPE:	walls, floor, roof, windows, doors, etc.	UA	U x A (BTU/hr ft^2 °F) x (ft^2)
INFILTRATION:	air exchange through leaks, cracks, ventilation	"UA"	VHC_{air} x Volume x ACH (.018 BTU/ft^3 °F) x (ft^3) x (no./hr)
PERIMETER:	contact with the ground via floor slabs, footings, basements	"UA"	F x P (BTU/hr ft °F) x (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 Tables E.11, E.12, E.13, pgs. 1582 - 1583.

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 E.27, pg. 1601.