Engineering Ethics Cases with Numerical Problems

from an NSF & Bovay Fund sponsored workshop

August 14-18, 1995

Texas A&M University

Civil Engineering Case 5

Heat Transfer Ethics Case

Author:

Wayne Helmer

(Helmer@engr.siu.edu)

Robert Walker

Suggested Courses:

Heat Transfer

Level:

Junior & Senior

I. Narrative

In designing a wall, it is useful to be able to calculate the heat transfer rate through a plane surface. See Figure 1, where typical wood-frame construction is illustrated. Wood siding is used on the outside surface of the wall followed by plywood sheathing. Glass mineral fiber insulation forms the main thermal resistance in the wall between the wood framing members (not shown). The inside surface is constructed of sheet rock.

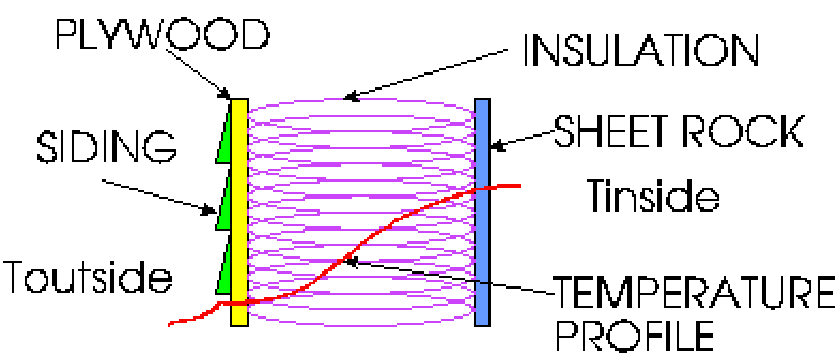


Figure 1. Typical House Wall Construction and Temperature Profile.

II. Engineering Principles

1. Identify the number of thermal resistances in this wall. Are there four resistances, or more, or less? What equation is used to calculate each resistance? Material properties and thicknesses are given below. A unit depth perpendicular to the page is assumed.

NOTE: The instructor may want the student to construct the thermal circuit at this point and make sure that the convection resistances on each side of the wall are included. Typical values are houtside = 1.0 W/m^2-K,

hinside = 3.5 W/m^2-K.

Table 1. Wall Material Properties

Material	Thickness (cm)	Thermal Conductivity (Watt/m-K)
Wood	0.95	0.14
Plywood	1.27	0.12
Glass Fiber	9.0	0.038
Sheet Rock	0.95	0.17

2. Calculate the heat transfer rate through the wall for the given winter weather conditions: Tinside = 23 C, Toutside = -15 C.

3. One of the practical problems associated with house construction in moist climates is that moisture from the inside of the house (due to water vapor given off from cooking, washing, people, etc.) will tend to migrate from the inside to the outside. If the moisture condenses in the glass fiber, it will degrade the effective conductivity of the material and cause other problems.

4. Calculate the point in the wall where the water will condense (if at all). If it does condense, will it cause a problem? Assume an indoor relative humidity of 50% and an outdoor relative humidity of 90%.

NOTE: The student will need to review psychometrics and determine the point in the wall where the temperature drops to the dew point temperature determined by the indoor drybulb temperature and the indoor relative humidity. The student will need to use the thermal circuit performed above and determine the surface temperatures on either side of the glass fiber insulation. A review of the psychometric chart is given below in Figure 2.

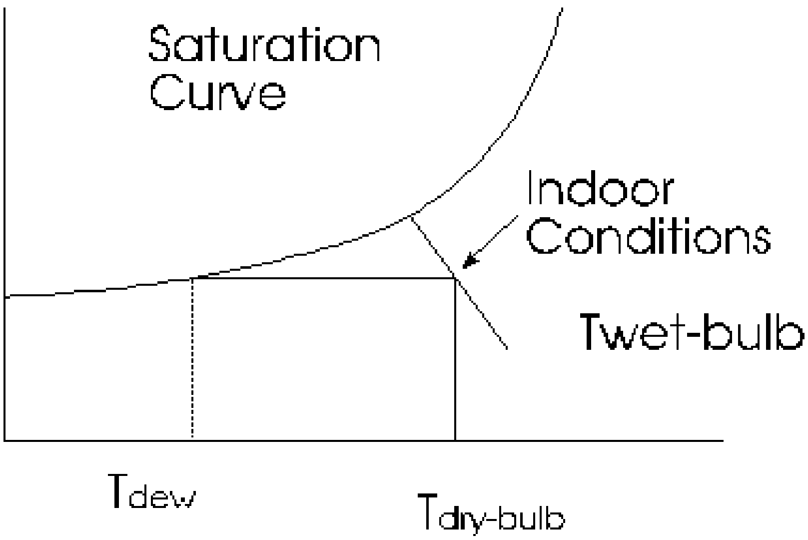


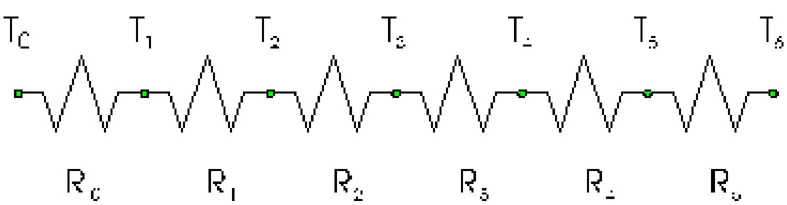
Figure 2. Psychometric Chart

III. Ethical Problem

You are an engineer working for a consulting firm responsible for designing the renovation of a series of old office buildings on a military base. Part of your job assignment is to design the new wall construction for these buildings. You decide to add 9 cm (3.5 inch) of glass fiber insulation to the wood-framed walls where no installation existed before. It is now March. One of the military specifications ("Mil Specs") that will become effective on January 1 of the following year requires that all insulating materials shall be designed and installed so that no vapor condensation occurs in the building walls. Your calculations show that moisture condensation will occur in the insulation in the walls during winter weather conditions. You share this with the engineering manager of your company and suggest that more expensive insulation (such as closed-cell polyurethane foam) should be substituted for the glass fiber insulation. He says that the construction modifications should be completed by the end of November, so the company will not need to comply with the new code. He instructs you to proceed with the current less expensive design.

IV. Engineering Solutions

The equivalent electrical circuit for the thermal system is shown below:



The circuit equation for the heat flow is q = T/Re

The equivalent resistance, Re, for the circuit is the sum of the individual resistances. The conduction resistances are given as Rcond = x/kA

where x is the thickness of the material in the direction of the heat flow, k is the thermal conductivity of the material, and A is the surface area of the material perpendicular to the heat flow. The convection resistances on either side of the wall are calculated from Rconv = 1/hA, where h is the surface heat transfer coefficient and A is the surface area perpendicular to the heat flow. Thus, the six resistances can be calculated as shown below:

Ro = 1/hoA = 1/[1(30)] K/W = 0.033 K/W

Rs = x/kA = 0.0095/[2(0.14)30] = 0.00113 K/W

Rply = x/kA = 0.0127/[(0.12)30] = 0.0035 K/W

Rins = x/kA = 0.09/[(0.038)30] = 0.079 K/W

Rsr = x/kA = 0.0095/[(0.17)30] = 0.00113 K/W

Ri = 1/hiA = 1/[3.5(30)] K/W = 0.010 K/W

The sum of these resistances is Re = 0.128 K/W.

The heat flow through the wall is

q = T/Re = [23-(-15)]/0.128 = 297 W

From circuit theory we know that the heat flow is the same through any resistance, or set of resistances in a series circuit . To find the outer temperature of the insulation we can use;

q = (T3-To)/(Ro + Rs + Rply)

= (T3-(-15))/(0.0033+ 0.00113 + 0.0035) = 297 W

solving T3 = -12.6 C.

We now need to determine whether the temperature of the insulation in the wall is below the dew point temperature of the air in the room. If so, the water vapor that diffuses through the wall will start to condense in the glass fiber insulation. Returning to the psychometric chart, using the indoor conditions of Tdrybulb = 23C and the Relative Humidity = 50%, we find that the dew point temperature is 12C. Since the lowest glass fiber temperature (-12.6C) is below this dew point temperature (12C), water vapor will condense in the insulation and a problem does exist!

Note: The temperature at the inner surface of the insulation can be calculated from

q = (T4 - T3)/Rins = (T4 -(-12.6))/0.079

Solving: T4 = 10.9C.

V. Ethical Questions and Solutions

1. List some of the known relevant facts of the case.

1. Vapor condensation will occur in the insulation for the current design.

2. The condensation is in violation of future military specifications.

3. Correction of the problem will require a more expensive insulation design.

4. The Engineering Manager is not concerned with future military specifications which will not occur before the completion of project.

5. Closed-cell polyurethane foam will accommodate the military specifications, but it is a more expensive material.

2. List some of the relevant factual questions whose answers you do not know.

1. Is the firm <u>required</u> by law to design in anticipation of future military specifications?

2. Will the consulting firm contract with military bases in the future?

3. What is the possibility of delays which may not allow project completion before January?

4. How much more expensive is the closed-cell polyurethane foam?

5. Will the additional cost of substituting polyurethane foam make the job unprofitable?

3. List some competing moral obligations illustrated in this case

One obligation is to be fair with the customer, in this case the U.S. Government. This obligation entails complying with all regulations, being honest about your interpretation of the regulations, and attempting to complete the project with minimal expense to the customer.

Another obligation is to be a loyal employee. Your firm wants to design the renovation so there will be no cost overruns, or at least as few as possible. This will make it more likely that the firm will get future contracts.

4. Give some courses of action that you could recommend to your manager. Try to find as many solutions as possible which satisfy the competing obligations. We can call these creative-middle-way solutions.

One option would be to call for the glass fiber insulation and try to complete the project before the new specifications take effect.

Another option would be to call for more expensive insulation that will meet the new specifications.

A third option would be to alert the U.S. military to the issue and ask for their preferences.

5. What course of action would you recommend?

The third option is the creative-middle-way solution. It might or might not be possible in the circumstances, but it would have the potential of being fair both to your firm and to the U.S. government.