

Project 1.3.4 Renewable Insulation

Introduction

The largest amount of energy consumed within the average home is related to maintaining adequate climate control through heating and cooling systems. To conserve energy and decrease expenses associated with climate control, proper home insulation techniques are required. Insulation technologies relating to materials and application have advanced throughout the home building industry with time. The home building industry once relied on straw and newspaper for insulating material. The industry currently utilizes technology such as fiberglass and blown expandable foam. Insulation material advancement is driven by consumers demanding insulation material designed for high insulation value along with positive occupant health and environmental impact. Many homeowners today are designing new “green” homes. To meet the needs of green consumers, insulation manufacturers are developing insulating materials made from recycled products such as jeans, t-shirts, and other low volatile organic products that can be treated with boric acid. Manufacturers have found that many green materials have other benefits to the homeowner as well, such as cotton’s ability to provide excellent soundproofing.

Equipment

* Computer
* Heat box apparatus
* Logger *Pro* software
* 2 stainless steel temperature probes
* Insulation materials
* Tape
* Standard and metric ruler

Procedure

Your team will design a renewable composite insulation material.

Design Constraints:

* Composite insulation material must produce minimum heat loss, representing good insulating value.
* Composite insulation material must have overall uniform thickness less than or equal to one inch.
* Composite insulation material must have consistent internal composition.
* Individual insulation material(s) must be environmentally friendly.
* Individual insulation material(s) must be recyclable.
* Individual insulation material(s) must be economical.
* Composite insulation material dimensions must not exceed the overall dimensions of heat box apparatus top.
* The change in temperature inside the box is directly related to the heat absorbed or released by the air in the box.

Design Evaluation Data Collection:

Pretest Data:

* Use a metric measurement device to calculate pretest data.
* The volume of air being heated is obtained by measuring the inside dimensions of the box.

|  |  |
| --- | --- |
| 1. Inner dimensions (m) | l =  w=  h= |
| 1. Volume of air (m3) | V = |
| 1. Description of insulation material |  |

Test Data:

* Plug two Stainless Steel Temperature Probes into two Go!Link connectors. Plug the Go!Link into one of the computer’s USB ports.
* Insert a temperature sensor with acquisition capabilities inside the acrylic top cover of the heat transfer apparatus.
* Place or attach your fabricated composite insulation material to the outside top surface of the heat transfer apparatus cover.
* Place a second temperature sensor with acquisition capabilities outside of the box to measure the ambient room temperature.
* Open the program Logger *Pro* on your computer by clicking Start > All Programs > Vernier Software > Logger *Pro* 3.8.
* Activate heat source and leave on for 20 minutes or until the inside temperature remains relatively constant.
* While the tester is heating up, set up Logger *Pro* to take data for 20 minutes.
  + - * + Click Experiment, Data Collection.
        + Change the experiment length to 20 minutes and the sample rate to 4 samples per minute.
        + Click OK.
* Turn the heat source off and collect temperature data for 20 minutes. To do so, click on the green Collect Data icon at the top of the Logger *Pro* program.
* Once all of your data is collected, save the Logger *Pro* document.
* Remove temperature probes from the heat box.
* Return the temperature probes and the Go!Link connectors to your teacher.
* You may obtain the necessary temperature data by examining the graph or using analysis tools in Logger *Pro*.

|  |  |
| --- | --- |
| 1. Heat source light bulb wattage | P = |
| 1. Initial internal temperature (°C) | T Initial 1 = |
| 1. Maximum internal temperature (°C) | T Max 1 = |
| 1. Final internal temperature (°C) | T Final 1 = |
| 1. Initial room temperature (°C) | T Initial 2 = |
| 1. Maximum room temperature (°C) | T Max 2 = |
| 1. Final room temperature (°C) | T Final 2 = |
| 1. Heating time(s) | t1 = |
| 1. Cooling time(s) | t2 = |

Design Evaluation Calculations:

Constants:

ρ: 1.20 kg/m3 (density of air, Greek letter rho)

Cp: 1000. J/kg °C (specific heat capacity of air)

All calculations are based on the combination of both your composite insulation material and the acrylic heat transfer apparatus material.

1. Mass of air being heated

* Select equation(s).
* List all known and unknown values.
* Substitute known values into equation(s).
* Simplify and solve for mass (m, in kg).

1. Energy gained by the air in the box during heating—Q (heat) in J (joules).

* Select equation(s).
* List all known and unknown values.
* Substitute known values into equation(s).
* Simplify and solve for energy gained Q (heat).

1. Energy lost by the air in the box during cooling—Q (cool) in J (joules)

* Select equation(s).
* List all known and unknown values.
* Substitute known values into equation(s).
* Simplify and solve for energy lost—Q (cool).

1. Net energy retained within the box—Q (net) in J (joules).

* Select equation(s).
* List all known and unknown values.
* Substitute known values into equation(s).
* Simplify and solve for net energy retained—Q (net).

1. A qualitative measure of your insulating ability is the difference between the maximum inside temperature and the maximum outside temperature (larger is better).

Tin(max) =

Tout(max) =

ΔT(max) =

1. Compare your results with those of some other teams.

Q(net): ΔT(max) = (team 1)

Q(net): ΔT(max) = (team 2)

Q(net): ΔT(max) = (team 3)

1. Extension: Use a thinner layer of insulation so that most of the heat of the box is escaping by conduction through the top. Use a lower-power light bulb to reduce the fire hazard, and leave the light bulb on until the temperatures reach equilibrium. At that time, the power exiting through the top area is equal to the power of the bulb. Solve for R:

P=A T / R

Conclusion

1. Explain how your house might lose energy through radiation, convection, and conduction.
2. What modifications could be made to your team’s insulation design that allow for more energy efficiency?
3. Which beverage would be more beneficial for cooling you on a hot summer day—a cup of ice cold water or a cup of hot cocoa? Justify your choice.
4. How do birds insulate their bodies to prevent energy loss on the skin’s surface?
5. Suppose that you are sitting close to a campfire. You decide to clean your glasses and notice that your eyes feel warmer without your glasses. Explain this phenomenon.
6. We wear winter coats and cover with blankets to stay warm in the winter. If the coats and blankets are not a source of energy, how do we stay warm?