TEACHER INSTRUCTIONS

Hot or Not

Objective: To show how materials can be designed to withstand very high temperatures.

Background Information: There are four different mechanisms by which heat can transfer: conduction, convection, radiation, and advection. Conduction occurs when two things are in physical contact with each other. Heat causes the atoms in a material to vibrate which then transfers energy to other atoms in a process called thermal conduction. In the vacuum of space, there is no matter and therefore no conduction of heat. Gases, such as air, contain very little matter in comparison with solids or liquids. They "insulate" heat from flowing. This is why porous materials like foam insulation and ceramic tiles, which contain a lot of air, are used to keep our houses warm.

A refractory material is chemically and physically stable at high temperatures and has good resistance to thermal shock. Refractory bricks are made from ceramic materials that can withstand extreme temperatures without melting. In addition, they contain a great deal of trapped air since they are so porous. When the brick is heated on one side, the heat cannot travel to the other side since there is so much insulating air in between. Tiles, similar to the ceramic refractory brick used in this demo, were used on the outside of the space shuttle to protect the ship and crew from the >1200°C temperatures achieved on reentry into Earth's atmosphere (Figure 1).

Metals can also be refractory materials. These types of refractory materials are often used as tools to work other metals at high temperature, light bulb filaments, and in furnaces used to manufacture steel and glass (Figure 2).

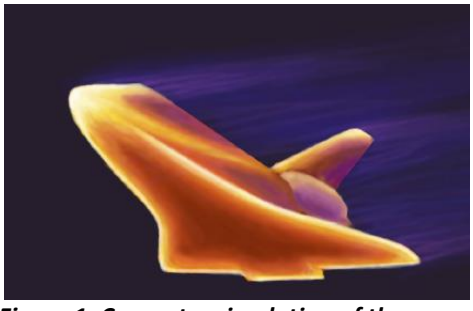

Figure 1. Computer simulation of the space shuttle upon re-entry. Because its surface reaches extremely high temperatures, it is covered in refractory ceramics.

Figure 2. Steelmaking – refractory materials are used in the crucible.

Demo Description: In this demo, a propane torch will be used to heat one side of a refractory brick. A thermometer will be used to monitor the other side of the brick, which should remain cool during heating.

Keywords:

- heat – the energy transferred from one body to another.
- temperature – the measurement of the amount of heat present in an object.
- insulator – a material that resists the flow of heat (e.g., ceramics or plastics).
- thermal conductor – a material that aids in the flow of heat (e.g., metals).
- refractory – a substance that is chemically and physically stable at high temperatures and is resistant to thermal shock.
- porous – an object having many small spaces (i.e., pores) that can hold a gas or liquid or allow a gas or liquid to pass through.

Materials List:

Items provided in the kit:

- 1 refractory brick
- 1 propane torch head

Items to be provided by the teacher/school:

- small propane tank (1 liter, generally found in the camping aisle at stores like Walmart®)
- thermometer (a variety of thermometers will work – the easiest to use is probably a meat thermometer since it is made to be "stuck" in a material)
- spark lighter or matches (also generally found in the camping aisle)

Safety Precautions: Be very careful not to touch the hot side of the refractory brick. Do not look directly at the flames of the torch.

Instructions:

1. Attach the propane torch head to the propane tank.
2. Show students the refractory brick.
3. Explain what refractory materials are and what they are used for.
4. Set up the refractory brick so that both sides can be seen and accessed. It is possible to hold the brick in your hand because the back side will remain cool.
5. Insert the thermometer on the side of the brick that will not be heated.
6. Heat the side of the brick without the thermometer.
7. Have a student read the temperature on the thermometer as the other side of the brick is heated.

Demo Delivery Hints:

1. If students are mature/responsible enough, allow several to take turns controlling the propane torch to keep them involved in the demo.
2. When the refractory brick is not in use for the demo, be sure to keep it in the included plastic baggie. If the plastic baggie becomes worn or dirty, replace it with a new one. (There is nothing special about the baggie included in the kit – feel free to replace it with a similar plastic bag). The refractory brick will slough off in small pieces if handled roughly and may also dent or crack into two pieces if hit against hard surfaces. If the brick cracks into two smaller pieces, the smaller pieces can generally still be used to run the demo as long as the piece is large enough to allow for heating on one side.

Troubleshooting: Do not put the thermometer on the side of the brick you are heating. It may melt! Be sure not to push the thermometer all the way through the brick as this will produce the same result as putting the thermometer on the heated side. When lighting the propane torch with a grill lighter, keep the flame turned down low or else the torch will blow itself out. Light it on low, and then turn the flame up as desired.

Cleanup/Replacement Parts: DO NOT TOUCH THE HOT SIDE OF THE BRICK! Place the brick in a safe place (out of the reach of students) and allow it to cool. Do NOT put the brick away until it has cooled completely. Use the thermometer to confirm that the temperature of the heated side has returned to room temperature. Tighten the knob on the propane tank and put everything back in the kit. Be gentle with the refractory brick.

Hot or Not

Discussion Questions to Ask Before the Demo

1. What is heat?

   Discussion: The energy (other than work) that is transferred from one body to another.

2. What causes things to heat up? How does heat transfer?

   Discussion: When heat travels, it must have physical matter to move through. It transfers by vibrating the atoms in a material which then transfers energy to other atoms in a process called thermal conductance. In the vacuum of space, there is no matter and therefore no heat.

3. What could prevent heat from transferring?

   Discussion: Gases, such as air, contain very little matter in comparison with solids or liquids. They "insulate" heat from flowing. This is why porous materials like foam insulation and ceramic tiles, which contain a lot of air, are used to keep our houses warm.

4. What uses would you have for materials that easily transfer heat? What uses would have for materials that prevent heat transfer?

   Discussion: Kitchen pots and pans are made out of metals, which generally have very high heat transfer coefficients. This is why we use them for tasks such as boiling water on a stovetop. Refractory materials are generally made out of ceramics and are highly porous, meaning they contain a lot of trapped air within the microstructure of the material. Refractory bricks similar to the one supplied for this demo were used on the NASA space shuttle to prevent overheating during atmospheric re-entry. Refrigerators and freezers are another example of items in a kitchen which have low heat transfer.

Discussion Questions to Ask During the Demo

1. Why is the heat not transferring through the material?

   Discussion: Gases, such as air, contain very little matter in comparison with solids or liquids. They "insulate" heat from flowing. This is why porous materials, like the refractory brick, do not transfer heat well. It contains so many pores full of trapped air that it significantly slows the transfer of heat to the other side of the brick.

2. What would happen if we exposed something else in the classroom to the heat of the propane torch (for example, the metal leg of a chair)?

   Discussion: The chair leg would begin to glow where exposed to the heat and slowly that glow would spread over a large area of the leg. If the torch is hot enough, it would likely cause the leg to melt and deform.

Discussion Questions to Ask After the Demo

1. What are different ways materials are made to stop heat from transferring?

   Discussion: The refractory brick in this demo uses pores, or empty areas filled with air, to prevent heat from transferring via conduction. Double pane windows have a similar concept, using an empty (gas-filled) area between the panes. Heat can be prevented from transferring via radiation by blocking the radiation, such as is done by a parasol to keep cool on a sunny day.

2. What would happen if this brick were dense (i.e., did not have pores)?

   Discussion: The refractory brick would allow the transfer of heat from one side to the other. However, due to the refractory nature of the material, no physical or chemical changes would occur. This means that the material would not melt, unlike most other materials exposed to the heat of a propane torch.

STUDENT QUESTION HANDOUT

Hot or Not

1. What is heat? How does it transfer from one object to another?

2. What is the difference between an insulator and a conductor?

3. What is special about the microstructure of the refractory brick?

4. How does that special microstructure impact the way the refractory brick responds to the heat of the propane torch?

5. Identify the mechanism of heat transfer (conduction, convection, radiation, or advection) in the following situations:
    a. Cooling your room using a fan
    b. A pan of vegetables on the stove
    c. Your driveway on a sunny summer day
    d. A chicken cooking in the oven