lesson plan

# Transporting Nuclear Materials

What are the challenges involved with designing and constructing containers for safely transporting radioactive materials?

## overview

### LESSON CONTEXT

In Canada there are about one million shipments of nuclear material each year. These include shipments to and/or from nuclear power plants, educational institutions, government agencies, commercial operations, hospitals and medical facilities. Containers in which nuclear materials travel are subjected to very rigorous testing to ensure that they will not leak during their journey.

### LEARNING GOALS

- Identify a design problem and generate possible solutions.
- Develop and implement a plan for the construction and testing of a prototype.
- Develop, evaluate and present a solution which meets the criteria of a Type A Nuclear Materials Transport package.

### LEARNING ACTIVITIES

In this lesson, students will use a design process to design, build, test and evaluate a container which simulates meeting the performance standards for a Type A Nuclear Materials Transport package.

### BIG IDEAS

An effectively designed and constructed Type A Nuclear Materials Transport package must safely withstand exposure to water, compression, dropping, shaking and puncturing.

**time**
70-85
MINUTES PLUS TIME OUTSIDE OF CLASS

**subjects**
SCIENCE
TECHNOLOGY
INDUSTRIAL ARTS

**skills**
CRITICAL THINKING
COLLABORATION
COMMUNICATION

## assessment & evaluation

### PRIOR KNOWLEDGE AND SKILLS

- Familiarity with the design process
- Familiarity with creating and implementing a plan
- Familiarity with methods of cutting and joining
- Experience working in cooperative small groups

### SUCCESS CRITERIA

- Students contribute to group tasks
- Students use tools and materials safely
- Students use an appropriate design process

### ASSESSMENT STRATEGIES

- Review of **Design Portfolio Assessment BLM**
- Review of **Design Project Student Self-Assessment BLM**

## resources & materials required

- PPT **Crash Test PowerPoint**
- DOC PDF **BLM – Design Brief** – one per student
- DOC PDF **BLM – Design Checklist** – one per student
- DOC PDF **BLM – Design Portfolio Assessment** – one per student
- DOC PDF **BLM – Design Project Student Self-Assessment** – one per student
- PDF Curriculum alignment

- Folders or Duo-tangs™ – one per student
- LCD projector or Interactive whiteboard
- Cardboard, wood or metal – as required per group
- Tools – as required per group
- Fasteners – as required per group
- Snack-sized resealable bag – one per group
- Sugar or sand – to fill each snack-sized resealable bag
- Aluminum foil – one roll
- Large plastic container or sink – one
- Water to fill plastic container or sink
- Newspaper – enough to fill interior of all groups' packages
- Weights, 1 kg size – 10
- Measuring tape – one per group
- Electronic scale – one per group

**DID YOU KNOW?**

In over 60 years, no one in Canada has ever been injured by the release of nuclear material during transport.

## preparation

- Students should be divided into small groups before the lesson.
- Set up necessary equipment to show a PowerPoint presentation.
- Students should have access to tools such as hacksaws and handsaws, sandpaper, tin snips, rulers, wood files, metal files, strip benders, pliers, scissors, spot welders, etc.
- Students will need access to materials for joining and sealing the packages such as nails, caulking, hinges, duct tape, rubber tubing, etc.

## minds-on

**20 MINUTES**

- Begin by showing students slide 2 of the **Crash Test PowerPoint**. Have a class discussion using questions such as:
  - » *What do you think is happening in this series of photographs?*
  - » *Do you think that the train is hitting the truck with the red container on purpose? Why?*
  - » *What was the condition of the red container after the crash?*
  - » *What do you think might be transported in the red container?*
- Explain that the red container in the photographs is called a Type B container and is used for shipping highly radioactive nuclear materials, such as cobalt-60 for radiation therapy and used nuclear fuel.

- Type B packages go through extreme testing.
  - » Slide 3 shows the Free Drop Test. In this test, the Type B package is dropped approximately 9 m (30 feet) onto an unyielding surface (will not deform itself).
  - » Slide 4 shows the Crush Test. In this test, an approximately 500 kg (1,100 pounds) steel plate is dropped from a height of approximately 9 m (30 feet) onto the Type B package.
  - » Slide 5 shows the Puncture Test. In this test, the Type B package is dropped from a height of approximately 1 m (40 inches) onto a steel spike with a diameter of 15 cm (6 inches).
  - » Slide 6 shows the Fire Test. In this test, the package is held at a height of approximately 1 m (40 inches) above burning fuel for 30 minutes at a temperature of 800 degrees Celsius. In addition, the packages go through an Immersion Test in which the package is immersed (submerged) in 1 m (approximately 3 feet) of water.
- Discuss the reasons for these extreme tests. Questions for discussion could include:
  - » *Why are extreme tests such as these necessary?*
  - » *In what real-life situations could some of these extreme conditions occur?*

## action

**20 MINUTES PLUS TIME INSIDE/OUTSIDE CLASS**

- Unlike Type B packages, Type A packages contain nuclear materials of medium activity and risk. They tend to be used for medical isotopes and radioactive materials used in research and medical applications.
- Have the students sit in their pre-assigned groups and distribute a copy of the **Design Brief BLM** to each student.
- Explain to the students that the purpose of this project is to design, test, evaluate and present a package which meets the criteria of a Type A Nuclear Materials Transport Package. At this point the students can fill in the "Our group will…" part of the brief.
- The successful package will safely transport "nuclear materials," which will consist of a snack-sized re-sealable bag filled with sugar or sand. The following are the requirements of the package and should be recorded by the students on their brief pages.
- The package must be:
  - » large enough to fit a snack-sized resealable bag but no larger than 15 x 15 x 15 cm;
  - » made of cardboard, wood or metal;
  - » lined with radiation shielding (aluminum foil);
  - » able to have newspaper between the resealable bag and the aluminum foil;
  - » able to open and close; and
  - » able to close completely (have a tight seal).
- Type A packages, like Type B packages, must also undergo performance testing to ensure that they will not leak nuclear materials if they are in an accident. The tests that the students will do on their packages closely mirror the real Type A package tests. Explain the criteria for the five types of tests and have the students record these on their brief pages.

### PACKAGE PERFORMANCE TESTS

1. Immersion test – package must be completely submerged in water for five minutes. No water must leak into the package and no nuclear material may leak out.
2. Crush test – five times the weight of the package must sit on the package for 24 hours. There must be no cracks in the package and no nuclear material may leak out.
3. Free drop test – package must be dropped from a height of 2 m. There must be no cracks in the package and no nuclear material may leak out.

### DID YOU KNOW?

The type of container used for transporting nuclear materials and the safety precautions put in place during transport depend on the type and the amount of nuclear material being transported. For small amounts of nuclear materials which have short half-lives and very low levels of radioactivity, all that is needed is a simple cardboard box. For larger amounts of highly radioactive nuclear material, such as used nuclear fuel, containers have been developed that are capable of remaining intact during and after catastrophic accidents such as being hit by a train, as was seen in the photographs.

4. Puncture test – a 6 kg weight must be dropped onto the package from a height of 1 m. There must be no cracks in the package and no nuclear material may leak out.
5. Shake test – package must be vigorously shaken for 5 minutes. There must be no cracks in the package and no nuclear material may leak out.

- Review the design process (see below). *Note: the order and terminology of steps varies from course to course and jurisdiction to jurisdiction – use the design process that students will be familiar with*. Students are to use the folders to collect and record information, observations and reflections for each step of the design process. These folders will be their design portfolios.
- You may also choose to provide students with the **Design Checklist BLM**, which can help them to check their progress and include all necessary stages of the design process.

## IMPLEMENTATION OPTIONS

- Instead of sugar or sand in a bag, students could use a raw egg.
- You may choose to have the students focus on a particular material, such as wood, and the tools and techniques used with the given material.
- Instead of having all groups do all of the performance tests, each group could choose three of the five tests.
- If the students wish, in addition to written observations, they could take digital photographs or video to include in their portfolios.

## DESIGN PROCESS

There are many different models for the design process, but they all have similar components or stages. For the purpose of this lesson, the design process includes:

Stage 1: Complete a design brief. Students will complete a detailed brief (such as the **Design Brief BLM**).

Stage 2: Research. Students will use a variety of sources to collect information pertinent to their design. This could include using the internet to look for examples of real Type A containers or to compare methods of forming watertight seals on lids. Sources should be appropriately cited.

Stage 3: Generate ideas. Students will brainstorm a number of ideas, ideally four or more. These initial ideas for solutions should include notes and simple sketches.

Stage 4: Choose a solution. Students should consider the strengths and weaknesses of their design possibilities and then choose a design which best suits the design brief for further development.

Stage 5: Develop the idea. Students create detailed working drawings to refine the initial design idea and prepare for construction. These drawings should be to scale and include measurements and labelling of materials, fasteners, etc.

Stage 6: Planning. Students will identify the key stages of construction and create a written construction plan showing the logical sequencing of the stages. This may take the form of a flow chart.

Stage 7: Construction. Students will construct a prototype based on their plan and working drawings. Students should adjust the plan as necessary and document any problems encountered.

Stage 8: Testing and evaluation. Students test their prototypes against the given criteria and reflect on the suitability of their design. If the prototype does not meet the criteria, the students will make changes to the original design and retest as necessary. Modifications should be recorded.

Stage 9: Presentation. Students present the successful prototypes to the class and discuss their processes, challenges, modifications and success.

## consolidation

30 MINUTES

- After each group has successfully created a prototype, have each student complete and submit a copy of the **Design Project Student Self-Assessment BLM** and hand in their design portfolios. If you wish, you can use the **Design Portfolio Assessment BLM** for assessing the portfolios.
- In addition, after all of the groups have successfully completed their prototypes, have each group show and discuss the characteristics of their prototype and the process they used. Any students who took photographs or video could also show these at this time. Questions for discussion with each group can include:
  - » *How did you come up with your ideas?*
  - » *How did research help you?*
  - » *Why did you choose the design that you did?*
  - » *What challenges did you face constructing your prototype?*
  - » *How effectively did you use your materials? Could you have used them more effectively?*
  - » *What were the strengths and weaknesses of your prototype in the performance tests?*
  - » *What would you do differently next time?*
  - » *Would you feel safe if you knew that your prototype was out on the road carrying nuclear materials?*

## extensions

- The students could watch videos of nuclear container testing by following the links in the Background Information section.
- Have the students create larger packages that can hold more nuclear materials (e.g. a 1 L pop bottle). How does this affect the design?
- Have the students research the design of a real Type A Nuclear Materials Transport package.
- How many students chose each of the materials (i.e. cardboard, wood, metal)? Which material was chosen the most? Discuss the choice of material with the students and examine the advantages and disadvantages of each material (e.g. cost, weight, water resistance, ease of fabrication, availability, etc.).

# additional resources

## CANADIAN NUCLEAR ASSOCIATION WEB PAGES

- **Transportation methods**
- **Transportation regulations**

# background information

**(Retrieved August 2019)**

- **Nuclear Flask Endurance Testing in USA – FreeScienceLectures**
  This video shows testing of large nuclear flasks. It includes trains and rocket-powered trucks running into flasks at high speed and a flask on a rocket truck ramming into a concrete wall and then set on fire.
- **Safe, Secure Transportation of Used Nuclear Fuel – Nuclear Energy Institute**
  A fact sheet from NEI explains some of the key facts around the safe transportation of used nuclear fuel.
- **Packaging and Transport of Nuclear Substances Regulations – Justice Laws Website, Government of Canada**
  The Canadian Department of Justice outlines the regulations for transporting nuclear material in Canada.
- **Packaging and transport of nuclear substances – Canadian Nuclear Safety Commission, Government of Canada**
  Regulations for packaging and transporting nuclear substances in Canada.
- **Frequently Asked Questions about Transporting Nuclear Substances – Canadian Nuclear Safety Commission, Government of Canada**
  The CNSC answers frequently asked questions regarding the transport of nuclear substances.
- **Regulating the packaging and transport of nuclear substances in Canada – Canadian Nuclear Safety Commission, Government of Canada**
  The types of packaging and transportation requirements needed to move nuclear materials in Canada.
- **Full-Scale Accident Testing in Support of Spent Nuclear Fuel Transportation – Sandia National Laboratories**
  A 2014 report prepared for the U.S. Department of Energy's Nuclear Fuels Planning and Transportation Project.
- **Road, rail, boat: Sandia transport triathlon puts spent nuclear fuel to the test – Sandia National Laboratories**
  The results of an eight-month, 14,500-mile test to gather data about transporting spent nuclear fuel in compliance with the Nuclear Safety Commission.