Collapsing Metal Can WIP

Keywords: Condensation, Gas Laws, Pressure, Vacuum

Meta Description

Exerting a change in pressure in a metal can by creating a vacuum inside, resulting in an implosion caused by the atmospheric pressure.

Learning Objectives

To investigate the effects of change in pressure.

To understand how a vacuum is created when water vapour condenses in a confined space.

Key Terms

Vacuum
A space void of matter.

Atmospheric pressure
The pressure caused by the weight of the atmosphere.

Condensation
The change of state from gas to liquid, commonly used to denote the formation of water from water vapour.

Method

Step 1
Pour some water in the metal can.

Step 2
Place the metal can on the fire stove and start heating.

Step 3
Wait a couple of minutes until the water starts boiling and water vapour is seen coming out of the can.

Step 4
Use safety gloves to seal the can using the rubber stopper and place the metal can in a tray of cold water.

Step 5
Pour more cold water on the metal can, to cool all the surfaces.

Step 16
Wait until the metal can implodes.

Precautions

1. Wear safety gloves when handling the hot metal can.
2. Make sure the water is boiling before sealing the can with a rubber stopper.
3. The metal can must be thoroughly cooled by placing it in a tray of cold water and also pouring water on it.

Narrative

Sometimes it might feel like the weight of the world is pressing down on your shoulders, but it turns out this is only partly true. You may not notice it, but the air around you and above your head is pressing down on you all the time. It’s actually pretty heavy! So why are we not crushed by the weight of it all? Well, it turns out, we have the same pressure in our bodies, applying an equal and opposite force against the air pressure. Things only get dangerous when these pressures are different. When the pressure inside you is greater than that of the air around you, you explode! If the pressure in your body is less than the air pressure, you implode! Either way, not a great way to go.

For safety sake we are going to use a metal can instead of your body to demonstrate the crushing power of the tonnes of air above your head.

Questions

What is happening to the water as it boils?
The water turns from a liquid to a gas, taking up more space.

What happens upon cooling the can with water?
The vapour inside condenses back to water, creating a vacuum.

Why does the can collapse?
The vacuum creates a change in pressure causing atmospheric pressure to crush the can.

Brief Explanation

When water is boiling in the metal can, water vapour occupies most of the volume within the can. As soon as the can is sealed with a rubber stopper no gases can escape. When the metal can start to cool the vapour inside condenses back to liquid which occupies much less volume, resulting in a rapid fall in internal pressure.

Standard atmospheric pressure exerts 101.3 kilopascals, which is more than sufficient to crush the metal can as shown in the demonstration.
(http://www.abc.net.au/science/articles/2011/07/13/3268575.htm)

Detailed Explanation

The ideal gas law describes the relationship between pressure, volume, and temperature within a system, it is described by the following equation:

$PV=nRT$,

where P is the pressure, V is the volume, n the number of moles, R is the universal gas constant and T is the temperature in Kelvin.

Assuming that the temperature is just above the boiling point of water, i.e. 100°C , for one mole of water we have:

P = 101325 Pascals
T = 373 K
R = 8.314 J K^{-1} mol^{-1}
n = 1 mol

Then,

V =nRTP

V = 0.0306 m3.

Meaning that one mole of water converted into steam occupies 0.0306 m3 of volume.

The mass of one mole of water is 0.018 kg and thus the density of one mole of water at atmospheric pressure is

density (steam)=0.018/0.0306

0.588 kg m-3

Now, the density of liquid water at room temperature is 1000 kg m-3, so the relative density of liquid water to steam at atmospheric pressure is:

density (water)/density (steam)=1000/0.588

= 1700

Thus, the volume of steam occupies 1700-times less volume when converted back to water. This explains why when the hot can, filled with water vapour is cooled, a pressure difference is created large enough for the external atmospheric pressure to completely crush the can. Notice that when the can is crushed the volume inside is minimized such that the external and internal pressure are equilised.

(http://www.abc.net.au/science/articles/2011/07/13/3268575.htm)

Applications and Research

Applications

In meteorology, the change in atmospheric pressure is used to forecast weather. Changes in atmospheric pressure cause mass air movement and thus changes in pressure can be a good indication of the upcoming weather conditions.
(http://www.theweatherprediction.com/habyhints/18/)

Research

In Ireland, research has been carried out on a hull design optimisation of a service vessel used in an offshore wind farm. The main objective of the research was in making better designs that can withstand high pressures.
(
https://www.researchgate.net/publication/312174757_Offshore_Wind_Farm_Service_Vessel_Hull_Design_O
)

Investigation

- Cool the metal can with different water temperatures and investigate the time it takes for the can to collapse.
- Investigate how different geometries of the metal container used can resist pressure differently.

Subject

Physics

Education

Secondary
Post Secondary
University
Informal

Time Required

~1 hour
Preparation: 15 mins
Conducting: 20 mins
Clean Up: 15 min

Cost

10 – 25 €

Recommended Age

10 – 12
13 – 16
>16

Number of People

2 participants

Supervision

Required

Location

Indoors
Outdoors
Festivals
Laboratory

Materials

Tray
Metal can or drum
Gas stove
Water
Beaker
Rubber stopper
Safety specs
Safety gloves

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Sources

Imploding drum

Offshore Wind Farm Service Vessel, Hull Design Optimisation/span>

CHANGES IN ATMOSPHERIC PRESSURE

Imploding Drum

Additional Content

Imploding Drum (Beginner)

Imploding Drum (Moderate)

Offshore Wind Farm Service Vessel, Hull Design Optimisation
(Advanced)

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