# Under Pressure

## Air Pressure and Desalinization aboard the *USS Hornet*

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From the USS Hornet Museum Education Department

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## About This Document

This program focuses on thermodynamics, states of matter, and how each is vital to the production of fresh water aboard the Hornet. Students will observe various objects in a bell jar and hypothesize about what occurred as a result of changing air pressure. The described demonstration is appropriate for students elementary through high school, and allows them to connect their findings to a real-world application.

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# Goals

In this program, students will:

- Observe and then describe matter in its various states

# Objectives

In this program, students will:

- Observe the effects of lowering air pressure on different objects.
- Gain an understanding of the use of lowered air pressure on the boiling point of water.
- Connect the air pressure experiments they observe to how water was desalinated on the USS Hornet.

# Big Questions…and Answers

*What happens to a gas/liquid/solid when the air pressure surrounding it changes?*

As pressure increases or decreases, the object's chemical properties will change significantly, causing a surprising, observable reaction.

*Why did the Hornet need so much fresh water every day?*

The Hornet was a steam powered ship. It needed fresh water to make steam for propulsion, electricity production, cooking, cleaning, and drinking.

# Program Overview

Demo and Discussion- 15-20 minutes

In this activity, students will observe how pressure affects matter. This is a demonstration on the instructor's part that encourages observation, hypothesizing, and scientific inquiry from students.

Suggested Materials:

Bell Jar with vacuum pump, hoses, and valves

Vacuum pump oil

Balloons

Jumbo Marshmallows

Warm Water

Thermos for keeping water warm

Dump Bucket

Small Plastic Beaker

Paper Towels

Ask the students to solve the following riddle:

What is all around us that we don't usually see, hear, feel, or smell? Air

Ask are there times when we do know air is there by:

Seeing – Smoke or fog

Hearing – Howling of the windy

Feel – Windy day or a breeze blowing

Smell – Smoke or salt air

Ask: Why don't we normally feel the air? Because it exerts pressure on all parts of our body at the same time and with the same force.

Ask: Has anyone ever been in an airplane and felt their ears pop? Why do you feel it? Because of a change in air pressure.

Explain that we are now going to look at how air pressure affects different objects and one of the ways the USS Hornet uses air pressure.

Explain how the Bell Jar and Vacuum Pump Work

Main parts are the motor, the pulley, the vacuum pump and the bell jar. Try an explanation like this: "The motor turns the pulley which runs the vacuum pump. The vacuum pump sucks most of the air out of the bell jar. As air is taken out, the pressure inside the jar is lowered."

Ask the audience what they think will happen to various objects if you place in them into the vacuum chamber. Encourage responses by giving positive feedback, even if ideas are not clear or correct. Use language such as "That's a good idea," or "Let's try it and see". After doing each demo, allow the audience the opportunity to try to explain what happens before offering your own ideas.

Perform the following three experiments:

1. The Balloon Expansion/Contraction Experiment

This demonstration shows the effect of pressure differences on a gas. As the vacuum is created in the jar, the air in the balloon expands because the pressure in the balloon is greater than the pressure in the jar. As the vacuum is released, the balloon contracts back to its original size, where the pressure inside the balloon is equal to normal air pressure.

a. Place a partly inflated balloon under the jar. Be sure not to cover the hole at the bottom of the plate.

b. Make sure the release valve (black) is closed and the base valve (yellow) is open (parallel to the hose).

c. Turn on the pump and ask the students to observe what is happening to the balloon.

d. Turn off the pump when the pressure differential gauge reads at least 15 in. Hg (before the balloon pops) and close the base valve. Ask the students what they think will happen to the balloon when you put the air back in. Will it go back to original size or deflate completely, etc.

e. Open the release valve and the base valve. Have the students observes what happens to the balloon.

2. The Marshmallow Expansion/ Contraction Experiment

This demonstration shows the effects of pressure on an object. Here, though, the structure of the marshmallow does not allow it to return exactly to its original shape. The air pressure in the marshmallow expands it in the vacuum, but when the vacuum is released, the normal air pressure is greater than that of the air in the marshmallow and it shrinks somewhat.

a. Place the marshmallow on the base and cover with the bell jar; make sure the release valve is closed and the base valve is open.
b. Before turning on the vacuum pump, ask students what they think will happen. Again remind students you are removing air. Turn on the vacuum pump to create a vacuum and ask students to observe what happens to the marshmallow.
c. Turn off the pump when pressure differential gauge reads at least 20 in Hg and before the marshmallow explodes.
d. Ask students to predict what will happen when you put air pressure back in.
e. Open the release valve and the base valve. Ask student to observe what happens.
f. Why did this happen? How was the balloon different from the marshmallow?

3. The Boiling Water at Room Temperature Experiment

This demonstration shows the effects of pressure on the boiling point of a fluid. In general, boiling points decrease as surrounding air pressure decreases. Here, by placing a beaker of water in a vacuum, it will begin to boil. However, the temperature will still be the same.

a. Place a small beaker with a little warm water in the bell jar. Make sure the release valve is closed and the base valve is open.

b. Ask students what the normal temperature is to get water to boil. 100 degrees Centigrade and 212 degrees Fahrenheit.

c. Show the students that the temperature is warm but not at boiling point.

d. Turn the pump on to create a vacuum. The water should quickly begin to boil and create vapor.

e. Turn off the pump when the gauge reads at least 20 in. Hg. And close the base valve.

f. Open the release valve and the base valve. (Water will stop boiling.)

g. Test water temperature with you finger.

h. Conclude that you can produce steam at a low temperature when the pressure is lowered in the vacuum.

# USS Hornet Reference Material

Engine Room

*How was low air pressure used on the USS Hornet to desalinate salt water?*

The USS Hornet needed 100,000 gallons of fresh water a day. But the Ship was not able to store a huge amount of water and it was at sea for 3 to 6 months at a time without docking. Therefore, the engineers had to devise device which would desalinate water. The device was the evaporator.

Fresh water was created from sea water by a three stage evaporation process. Sea water would be taken in through as screening sieve. This would be heated to about 60 degrees. The heated sea water would be pumped into a vacuum unit and would produce vapor. The vapor would rise to a cooling unit and be reformed into water. The leftover brine would drain into a dump unit to go back to the sea. The new water would be put into another vacuum unit and again vaporized. Again the vapor would rise and be cooled into fresh water and the brine would go back to the sea.

*Why did the Ship need so much fresh water every day?*

The Hornet was a steam powered ship. It needed fresh water to make steam for propulsion, electricity production, cooking, cleaning, and drinking. The fresh water from the evaporators were pumped into the boilers in the Fire Rooms. There the fresh water was first heated to 650 degrees F. to produce wet/auxiliary steam. Some of this auxiliary steam was sent to the turbines of the electrical generators and some was cooled for potable drinking water. The other part of the auxiliary steam was sent to the superheater. The superheater created steam to 850 degrees F. This was called dry steam. Dry steam was needed for the propulsion turbines. The dry steam contained almost no moisture. Any moisture could create water molecules in the propulsion turbines. These molecules could act as pebbles and destroy the turbines.

*Describe what it was like to work in the Fire Room.*

The average temperature in the Fire Room was around 110 degrees F. The noise level was extremely high. The boilers used Bunker C oil. Bunker C oil is extremely dense. Bunker C needs to be heated to 160 degrees before it can be fed into the boilers. The oil stuck to just about everything. Sailors worked 4 hours on and 4 hours off. Many of those who worked in the Engine Rooms went deaf from the noise.

# *Next Generation Science Standards*

| Grade Level | Standards |
|---|---|
| 4 | *Energy*<br><br>4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.<br><br>4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. |
| 6 | *Energy*<br><br>MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.<br><br>MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. |
| 7 | MS-PS1 Matter and Its Interactions<br><br>MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.<br><br>MS-PS1-4. Develop a model that predicts and describes |

| | |
|---|---|
| | changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. |

# Links and Credits

This program was created in conjunction with a grant from the Office of Naval Research, and was adapted from the following lesson: http://www.ussnautilus.org/education/pdf/stemlessons/THEGREATESCAPE_MEZIC_activityFour.pdf

Docent Scott Zirger has created a wiki for the ship containing a wealth of information: https://en.wikipedia.org/wiki/User:Szirger/Books/USS_Hornet_Reference_Material