UNITED STATES MARINE CORPS

LESSON PLAN

ATMOSPHERIC PRESSURE

INTRODUCTION:

1. Gain Attention. Experiment: Get an empty plastic gallon milk jug with a cap top. Fill it about a quarter of the way full with very hot water. Cap it tightly and let it stand for about an hour. What did you expect to happen? What did happen?

The milk jug will crumple in on itself. When you added the hot water, it caused the air temperature inside the jug to rise. While the container was sealed no air could get into or out of the jug. When the water inside the jug cooled, the air cooled and caused the pressure inside the jug to decrease. As the pressure on the inside walls of the jug decreased, the walls of the jug collapsed. Since there wasn't enough air pressure inside the jug to offset the air pressure on the outside of the jug.

2. Overview. Pressure is one of the most important concepts to understand when analyzing and interpreting weather phenomena, yet it can be one of the most complex subjects to understand the dynamics of. This period of instruction is provided to aid in the fundamental concept of pressure (atmospheric) and the changes that occur in it.

3. Introduce Learning Objectives.

a. Terminal Learning Objective. Without the aid of references, but in accordance with the instruction, explain the concept of atmospheric pressure and its associated relationships.

b. Enabling Learning Objective(s). Without the aid of references, but in accordance with the instruction, the student(s) shall:

(1) Explain what creates the pressure within the atmosphere.

(2) Describe how density and temperature affect atmospheric pressure.

(3) Explain why pressure decreases with height.

4. Method/Media. This period of instruction will be taught using the lecture method with aid of QMMCBT-001 “Introduction to the Dynamics of the Atmosphere”.

5. Evaluation. The student(s) shall not be evaluated at the end of this period of instruction; however, there will be a question and answer period.

TRANSITION. An explanation of pressure can be described by discussing the atmospheric parameters that affect pressure. These parameters are expressed in the *Equation of State*.

BODY:

1. Understanding Atmospheric Pressure.

a. Gas molecules, unlike solid or liquid molecules, are not strongly bonded to one another, but move freely about filling all space that is available to them. When gas molecules collide into each other, as they frequently do under normal atmospheric conditions, they bounce off of each other like elastic balls. If a gas is confined within a container, its sides restrict the motion, much like the walls of a racquetball court redirect the motion of the racquetball. The continuous bombardment of gas molecules along the sides of the wall exerts an outward push that we call air pressure. Although the atmosphere is without walls, the molecules are confined from below by the Earth's surface and effectively from above because the force of gravity prevents their escape.

b. *Atmospheric pressure* is the force exerted by the gas molecules on some area of the Earth's surface or on any other body, including yours. Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air above that surface. In the diagram below, the pressure at point "X" increases as the weight of the air above it increases. The same can be said about decreasing pressure, where the pressure at point "X" decreases if the weight of the air above it also decreases. The atmosphere exerts pressure on every solid or liquid surface it touches. The pressure is omni directional, exerting pressure equally in all directions – up, down, sideways, and obliquely. Even though we cannot feel the constant bombardment of air, we can easily detect changes in it. When one experiences their ears "popping" as the ascend or descend in an aircraft, its because of the pressure changes that are occurring outside of the eardrum. The "popping" comes about as air collisions inside and outside of the eardrum begin to equalize.

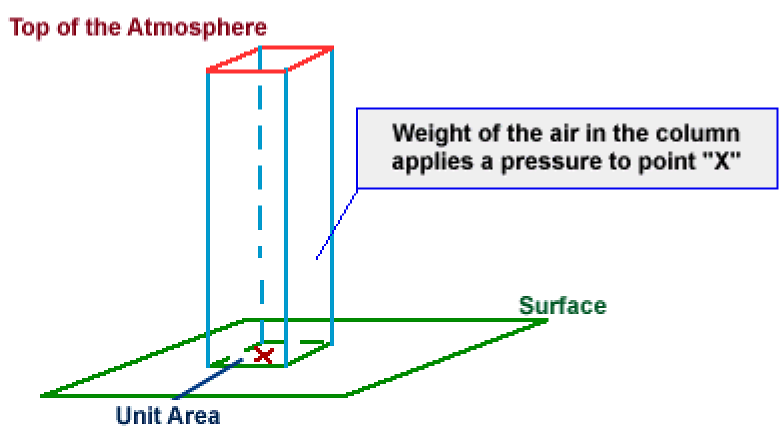

Figure 1 – Atmospheric pressure.

c. At sea level, the pressure that is exerted by the atmosphere is 14.7 pounds per square inch. This value drops with increasing altitude. Atmospheric pressure is not simply a "weight" from above, though every square inch of any exposed surface (i.e. animals, humans, vegetation, etc..) at sea level is exposed to 14.7 pounds of pressure per square inch. However, we are not sensitive to this pressure burden because the fluids and cells of our bodies contain air at the same pressure. There is an exact balance between inward and outward pressure.

TRANSITION. We have briefly introduced the concepts of atmospheric pressure. The next section introduces atmospheric parameters and formulas that aid to the understanding of the fundamental pressure concepts.

2. Pressure Formulas and Associated Parameters.

INSTRUCTOR NOTE: AFTER THE INTRODUCTION TO EACH FORMULA, PHYSICALLY DEMONSTRATE VARIABLE RELATIONSHIPS.

a. Equation of State. This equation shows the interdependency of pressure, density and temperature. It is known as $P=\rho RT$, "P" is the atmospheric pressure, "ρ" is atmospheric density, "R" is the gas constant for dry air, "T" is the temperature of the air measured in Kelvin (K).

b. Pressure. The formula to compute pressure is known as $P = F/A$, where "P" is the atmospheric pressure, "F" is the amount of force, and "A" is the area.

(1) Force. (Recall) The formula for force is known as $F=ma$, "F" is the amount of force, "m" is the mass of an object, and "a" is the acceleration of an object.

(1) Weight. The known formula for weight is $W=mg$, where "W" is the weight of the object, "m" is the mass of the object, and "g" is acceleration due to gravity (gravity held constant at $9.8m/s^2$).

c. Density. The formula to compute density is known as $\rho= m/V$, where "ρ" is the atmospheric density, "m" is amount of mass, and "V" is volume (recall that volume is length times with times height or depth).

(1) *Density* is the amount of matter in a unit volume. If you have a 10-lb object that is in the shape of a cube that's length is 1 foot, the density material is 10 pounds per cubic foot ($10lb/ft^3$).

(2) The density of solid material will be the same anywhere (on earth, the moon, or in space). The density of liquids will vary slightly from one location to another. The density of gases have an extreme variance with location because a gas will expand as far as the environmental (atmospheric) pressure will allow it to expand.

(3) For example, if you have 100 pounds of gas in a container that has a volume of 1 cubic foot, the gas density will be $100lb/ ft^3$. But if you were to transfer the 100 pounds of gas into a container that has a volume of 5 cubic feet, the gas will expand to fill up the larger volume. There are the same number of gas molecules that were in the smaller container, but now the gas molecules are allowed to expand over a volume five times as large. Therefore the gas density in the larger container is only $20lb/ ft^3$ (100 lbs divided by 5 cubic feet). The density of a gas is proportional to the pressure on it and the pressure a gas exerts is proportional to its density. The denser the gas, the greater pressure it will exert.

b. Temperature. If the air is heated, molecules will become more agitated and their speed increases. This increase in speed produces a greater force to their collisions and results in higher pressure. Therefore, holding all other variables constant (mainly volume), an increase in the temperature of a gas produces an increase in pressure and a decrease in temperature produces a decrease in pressure. By knowing this, one might conclude that the air pressure will be high on warmer days and lower on cooler days. But, in fact, the opposite is true.

3. Density Versus Temperature. As previously stated, the pressure of a gas is directly proportional to its density and temperature. This relationship can be explained by several different equations referred to as the gas law. Notice how we discussed that temperature was directly proportional to pressure "holding all other variables constant". Realistically, when air is heated, there is no control on its volume and therefore the air expands. This expansion now causes a decrease in density because of an increase in volume (refer back to the density paragraph). An increase in the temperature of an air parcel will cause a decrease in density, which will in turn, decrease the pressure. This is why warm air is typically associated with lower atmospheric pressures.

TRANSITION. Atmospheric pressure is closely related to density and temperature. Variations in any one of the three can cause changes in the other two. The next subject explains how and why pressure decreases with height.

4. Pressure With Height.

a. The number of air molecules above a surface changes as the height above the ground changes. For example, there are fewer air molecules above 50 kilometers (km) than there are at 12 km. The number of air molecules above a surface decreases with height due to gravity (which is always held constant at $9.8\ m/s^2$).

b. Most of the atmosphere's molecules are held close to the Earth's surface due to gravitational pull. Because of this, air pressure decreases rapidly at first, then more slowly as you ascend in the atmosphere. In the lower atmosphere, the molecules are closer together and there are many more collisions, a condition that produces higher pressure. In the upper atmosphere, gas molecules are farther apart (due to less of a gravitational pull) and collide with each other less frequently, a condition that produces relatively lower pressure.

OPPORTUNITY FOR QUESTIONS:

1. Questions from the Class. At this time are there any questions pertaining to any of the material that has just been presented?

2. Questions to the Class. There are no questions for the student(s) at this time.

SUMMARY: During this period of instruction, atmospheric pressure was defined, as well as, the relationships as to how density, temperature, and pressure all interact together. By combining the presented information, one should have a fundamental understanding of pressure and as to why pressure changes on the surface and in the upper levels of the atmosphere.

<u>REFERENCE</u>:

The Atmosphere, An Introduction to Meteorology. Frederick K. Lutgens and Edward J. Tarbuck.

Physical Geography, A landscape Appreciation. Tom L. McKnight and Darrel Hess.

Department of Atmospheric Sciences (DAS) University of Illinois. Last accessed 8/8/2004. http://ww2010.atmos.uiuc.edu.