FUNDAMENTALS OF PHOTOVOLTAICS FOR THE FIRE SERVICE

TOPIC: 3: Photovoltaic Performance

TIME FRAME: 0:30

LEVEL OF INSTRUCTION: Level 1

BEHAVIORAL OBJECTIVE:

Condition: Given a written test

Behavior: The student will confirm their knowledge of photovoltaic history and performance by completing the written test.

Standard: With a minimum 80% accuracy according to the information contained in:

- <u>Fundamentals of Photovoltaics for the Fire Service</u>, Rodney Slaughter, September 2006

MATERIALS NEEDED:

- Writing board or pad with markers/erasers
- Appropriate audiovisual equipment
- Appropriate audiovisual materials

REFERENCES:

- <u>Fundamentals of Photovoltaics for the Fire Service</u>, Rodney Slaughter, September 2006

PREPARATION: In this section we are going to discuss how a photovoltaic cell works, what it is made of, and the other components essential to the operation of the system. Understanding how the system operates is the key to working around PV systems safely. We will also discuss other solar technologies as they relate to emergency response such as skylights and solar water heaters.

PRESENTATION	APPLICATION
	Slide 1 - Agenda “PV Performance”
I. OBJECTIVE	
	Slide 2 – Behavioral Objective
A. At the end of this section you will be able to cite historical milestones in the development of PV’s and B. Recall the factors that effect PV performance	
	Slide 3 – Historical Brief **Instructor Note:** The information highlighted in *Blue* provides additional historical background, not found in the text
II. PV Historical Brief A. *From the dawn of mankind, people have used the energy from the sun* 1. *In the 7th Century B.C. magnifying glass was used to make fires* 2. *In the 3rd century B.C., Greeks and Romans used mirrors to light torches for religious purposes* a) *By 20 A.D. the Chinese were doing the same* 3. *In 212 B.C., Geek scientist Archimedes focused sunlight, using reflective bronze shields, to burn wooden ships*	

PRESENTATION	APPLICATION

a) *The Greek Navy conducted experiments in 1973 and successfully set fire to a wooden boat at 50 meters*

4. *In the 6th Century A.D. Sunrooms on houses and public buildings were so common that the Justinian Code provided "sun rights" to ensure individual access to the sun.*

B. 1839 - French scientist Edmond Becquerel discovers the photovoltaic effect

1. He was experimenting with an electrolytic cell made up of two metal electrodes placed in an electricity-conducting solution—electricity-generation increased when exposed to light

2. *Edmond was 19 years old when he made this discovery*

C. 1873 - Willoughby Smith discovered the photoconductivity of selenium

D. 1876 - William Grylls Adams and Richard Evans Day discover that selenium produces electricity when exposed to light

1. Selenium cells didn't convert enough light to energy, the experiment proved a solid is capable of turning light into

PRESENTATION	APPLICATION

electricity

E. 1905 - Albert Einstein published his paper on the photoelectric effect

   1. At the same time he also published his paper on his theory of relativity

      a) Einstein wins the Nobel Prize for his theories in 1921

F. *1914- The existence of a barrier layer in photovoltaic devices was noted.*

G. *1916 – Robert Millikan provided the experimental proof of the photovoltaic effect*

H. 1918 - Polish scientist Jan Czochralski developed a way to grow single-crystal silicon

I. *1947- Passive solar buildings in the US were in demand as a result of scarce energy during the prolonged World War II.*

   1. *Libby-Owens-Ford Glass Company published a book highlighting the country's 49 greatest solar architects*

J. 1954 - The photovoltaic technology is born in the United States when Bell Labs developed the silicon photovoltaic (PV) cell

PRESENTATION	APPLICATION

1. *This was the first solar cell capable of converting enough solar energy into power to run everyday electrical equipment*

2. *Bell Telephone Laboratories produced a silicon solar cell capable of producing 4% efficiency and later achieved 11% efficiency.*

Slide 4 – Historical Brief

K. 1958 - The Vanguard I space satellite used a small (less than one watt) array to power its radios

1. *PV became the energy source of choice for space applications*

L. 1962 - Bell Telephone Laboratories launches the first telecommunications satellite, the Telstar (initial power 14 watts)

M. 1964 - NASA launches the first Nimbus spacecraft—a satellite powered by a 470-watt photovoltaic array

N. *1976- University of Delware builds "Solar One" the first PV/Thermal house*

O. *1976- RCA Laboratories fabricate the first amorphous silicon PV cells*

P. 1982 - The first, photovoltaic megawatt-scale power station goes on-line in Hisperia, California with a 1-megawatt capacity system

PRESENTATION	APPLICATION
Q. 1982 - Worldwide photovoltaic production exceeds 9.3 megawatts R. 1983 - ARCO Solar dedicates a 6-megawatt photovoltaic substation in central California. The 120-acre, unmanned facility supplies the PG&E's utility grid with enough power for 2,000-2,500 homes S. 1984 - The Sacramento Municipal Utility District commissions its first 1-megawatt photovoltaic electricity generating facility T. *1993- PG&E completes installation of the first grid-supported photovoltaic system in Kerman, California* U. *The National Renewable Energy Laboratory develops a solar cell from indium phosphide and gallium arsenide the first cell to achieve 30% conversion efficiency* V. 1999 - Cumulative worldwide installed photovoltaic capacity reaches 1000 megawatts W. *2004- The California Fire Service started making inquires about PV safety to SMUD and PG&E* X. Two recurring themes in this historical brief are:	

PRESENTATION	APPLICATION
1. The increased amount of PV energy production worldwide and 2. The conversion efficiency of the developing PV technologies which brings us to the “PV Performance” discussion	
	Slide 5 – PV Performance
III. PV PERFORMANCE A. Photovoltaic technology does not convert 100% of the Sun’s energy into electricity B. The highest efficiency PV technology is used on satellites and the Space Station, where cost is less of a consideration 1. These types of PV cells are able to convert as much as 30 % of sunlight into electricity 2. The highest efficiency PV products in conventional buildings convert up to 20 % of sunlight into electricity C. Environmental factors like 1. Overcast days caused by clouds and smog can lower system efficiency	

PRESENTATION	APPLICATION
2. Site factors: chimneys, trees and nearby buildings can shade the panels greatly reduce the output for the entire array	
D. And, like people themselves, PV systems operate best within a comfortable range of temperatures	
1. PV output is greatly reduced when the temperature of the individual cells goes above 90 degrees Fahrenheit	
2. Panels are installed on a racking system that lifts the panels off the roof to allow air to circulate around and cool the modules	
3. Extreme cold temperatures can have the opposite effect	
4. Increased output of 30 to 40% has been recorded in cold temperatures with clear days, and sunlight reflecting off snow banks	
	Slide 6 – PV Performance
E. To achieve peak performance, sunlight should strike the PV panel at a 90 degree angle	
1. Of course, the sun changes position during the day, and between seasons	

PRESENTATION	APPLICATION

2. For this reason a PV designer conducts a site inspection to determine availability of sunshine throughout the year, including a number of site specific characteristics such as

    a) average daily insolation,
    b) site latitude,
    c) magnetic declination (true south),
    d) tilt angle and
    e) site specific information such as local weather and climate,
    f) all the while keeping an eye out for shading obstacles

3. PV systems in the Northern hemisphere will be orientated towards true south

F. Installers typically underestimate the PV module output by 15 to 25% from the manufacturers tested output

1. This allows a buffer in the specifications to ensure that the installed system will meet the building owner's energy needs

2. Another factor in PV efficiency is the output of the system and the fact that PV cells degrade about .25 to .5% every year

3. Solar panels will last for at least 25 years

4. These systems may actually outlive many of their original owners

Slide 7 – PV Concepts

IV. Photovoltaic Concepts

A. Electricity refresher and terminology

B. Electricity is the flow of electrons through a conductor.

C. Electrical concepts associated with this flow of electrons—voltage (volts), amperage (amps) and wattage (watts)

1. Voltage is the measure of electrical potential between two points

2. The unit of force, or pressure, it takes to motivate electrons to move through a circuit is measured in volts

3. The rate at which the electrons flow through the circuit is measured in amps

4. Wattage is simply a measure of the amount of electrical power provided by the circuit

5. A watt is the rate an appliance uses electrical energy, or rather the amount of work done when one amp at one volt flows

PRESENTATION	APPLICATION
through one ohm of resistance 6. One watt is equivalent to 1/746 horsepower 7. A watt is the product of voltage (volts) multiplied by (amps)	
	Slide 8 – Ohm's Law
D. Ohm's Law 1. Ohm's Law is a mathematical equation to calculate these terms when you know at least two of the values 2. The Ohm's formula is: a) Volts x Amps = Watts 3. If your circular saw that draws 7.5 amps of power when plugged into a 120 volt wall outlet, it will consume, 7.5a X 120v = 900 watts of power 4. You can flip this equation around to find other values 5. Watts ÷ Amps = Volts and Watts ÷Volts = Amps 6. This formula is important when calculating the energy demand of the building	
	Slide 9 – Watt Hours

PRESENTATION	APPLICATION
E. The watt-hour is an important measurement of how much energy is being used 1. To calculate watt hours you need to know the rated wattage for the appliance and how the long the appliance stays on 2. Add together all the appliances in the building and you get an idea of how many potential watt-hours maybe needed by the system	
	Question: How many watt-hours do you estimate are being used in this classroom right now?
3. Once you get into these numbers you will see that the kWh consumed in the normal course of living are substantial a) One thousand watts consumed over the period of one hour is one kilowatt hour, (or kWh) F. Why is this information so important to PV system designers? 1. PV systems need to be sized to meet consumer energy use 2. PV systems are expensive and the average American consumer uses a lot of electrical energy	

PRESENTATION	APPLICATION
3. The bigger the system, the higher the out-of-pocket expense to the building owner 4. A PV system cannot deliver a constant amount of energy every day in every season 5. Installers will analyze the energy usage and expectations 6. Energy conservation plays a significant role in lowering your energy usage	
V. SUMMARY A. The physics of electricity never change, regardless of how the electricity is generated B. There are a number of factors that affect overall system performance including the technology itself C. Recognizing these factors is another key to personnel safety when working around PV systems.	Slide 10 – Summary