Nuclear Power and Radiation – Facts, Myths and Risks

PRESENTATION	OTHER	EXAM	Total Time
45 minutes		0	45 minutes

Table Of Contents

I. General Introduction

A. Introduce self and/or guest(s)

Slide 1 & 2

1. Introduction - Title Slide
2. Review Resume
   a. Total of 45 years of Nuclear experience (Navy, Point Beach and Consulting)

Slide 3

3. Overview of Presentation
   a. There is much difficulty in discussing nuclear power due to the very nature of the topic.
      1) We all have a primitive fear of those things we cannot control. e. g. flying on a plane.
      2) The perception is that if a nuclear event occurs there is no escape from the radioactive cloud. That the danger will be fast and everywhere.
         a) This is a false perception.
         b) Think of the accident in Japan
            (1) How many people died because of the earthquake and the tsunami that followed? Answer - Over 10,000 died.
            (2) How many people died from radiation at the plant or the surrounding area? Answer - None
            (3) What pictures do you remember from the earth quake, tsunami and the Fukushima event? – The explosion at the nuclear plant.
            (4) What were the headlines – "Nuclear Disaster at Fukushima"
         c) The media loves disasters. 500,000 people die in car accidents each year world-wide. 300 people die in a plane crash. What makes the front page? So the media coverage isn't going to help the industry state its case.
      3) Nuclear power remains a topic that is highly technical (and therefore hard to be understood), political and confrontational making it mysterious, secretive and represented by a mushroom cloud, a mutated fish or the TMI cooling towers.
   b. I personally no longer have a stake in the future of nuclear power. But I do care about the future of the United States and my children and grandchildren. I feel we must eliminate our reliance on foreign oil and, for that matter, fossil fuels.
   c. My desire is to provide an overview of nuclear power to eliminate confusing or misunderstood ideas.
   d. A few questions may be asked during the presentation, but that may limit time for completion of this session

II. Presentation

Slide 4

A. Current Use of Nuclear Power

1. World Use
   a. Total of 435 nuclear electrical generating plants worldwide
   b. United States – 104 plants
      1) Of the 104, 71 are Pressurized Water Reactors and 33 are Boiling Water Reactors
      2) The terms PWR and BWR will be explained in detail later, but the difference is basically the additional loop or barrier between the reactor and the turbine
   c. Other countries of note
      1) France has 58 reactors
      2) Japan has 50 reactors
      3) Russia has 33

Slide 5

2. United States Plants
   a. 104 total but will be one less in 2013
   b. Kewaunee is scheduled to be shutdown in June of this year
   c. Under construction in US
      1) Two are currently being built
      2) Volgtle III and IV in Georgia
   d. Compared to those under construction outside the US
      1) India – 7
      2) Russia – 11
      3) China – 26

Slide 6

   e. There are 26 planned reactors in the US, however several have suspended their application to go forward over concerns on new regulations.
      1) Due to the Japanese plant earthquake and tsunami event in 2011 and
      2) The indecisiveness regarding the solution for high-level waste disposal.

Slide 7

3. Wisconsin Nuclear Plants

a. Kewaunee and Point Beach

b. About 18% of the electrical power used in the state comes from nuclear power.

1) Service to approximately 800,000 homes

Slide 8

c. Kewaunee Nuclear Station

1) 574 MWe single unit

2) Currently owned and operated by Dominion Power (Richmond Va.)

3) Built by WPS, Madison Gas and Electric and Wisconsin Power and Light (Alliant now) Operated by WPS until sold in 2005.

4) Scheduled for shutdown in June 2013

5) Natural gas most likely will make up for the lost nuclear electrical generation

Slide 9

d. Point Beach

1) Two units around 512 MWe each.

2) Built and operated by Wisconsin Electric (Now WE Energies) until purchased by FP&L in 2007

Slide 10

B. Radiation Facts and Risks

1. Sources of Radiation in our world

a. Natural Occurring (approx 50%) or Background radiation (about 300 mR/yr)

1) Terrestrial (Dark blue) – the earth, soil, rock, concrete materials, etc.

a) Includes burning coal – smoke and fly ash (exposure to those living within ¼ mile (about 20 mrem/year)

b) High levels found in certain ores (Monazite for example – found in Brazil)

2) Internal (Yellow) – radioactive materials in our bodies

a) Mostly potassium-40 and C-14

b) Bananas have potassium in them.

c) Some college students have developed a chart that provides a way of comparing amounts of radiation from different sources, with the ingestion of 1 banana being equal to 1 banana dose (0.01 mR)

3) Space (Green)– cosmic radiation left over from big bang

a) positive ions interact with the upper atmosphere

b) x-rays, alpha particles, muons and protons are created

c) The higher the elevation, then the higher the exposure

Examples

(1) Flying in a plane from coast to coast is about 4000 banana doses

(2) Spending one day in Denver vs one day in Green Bay, about 12 banana doses

4) Radon & Thoron (Red)

a) Radioactive gaseous byproducts (daughters) from the radioactive decay of naturally occurring radioactive materials in the earth.

b) Uranium and Thorium

(1) Found in rocks in trace amounts

(2) Seeps up through the ground

5) Total natural occurring - background radiation is about 30,000 banana doses in the US. (3 mSv = 300 mrem)

Slide 11

b. Man Made (approx 50%)

1) Medical exposure is about 48% of the total man-made radiation exposure and half of all exposure - about 30,000 banana doses on average (3 mSv = 300 mrem)

a) Tomography (light blue) – CAT Scans PETs, TEMs or SPEC

(1) Types of tomography with radiation associated with them

(a) CAT – x-rays

(b) PET – x-rays

(c) SPEC – gamma

(d) TEM – electrons

(2) Dose

(a) A simple x-ray of an arm is about 200 banana doses (2 mrem)

(b) A dental x-ray is about 500 banana doses (5 mrem)

(c) A brain CT Scan is about 20,000 banana doses (200 mrem)

b) Fluoroscopy – Continuous X-rays (highest dose)

(1) Conventional

(a) Red Goose shoe stores – saw your toes move

(b) Heart - looking for blocked arteries, installing stints

(2) Interventional - Use contrast agents – barium x-rays

c) Nuclear Medicine - examples

(1) Diagnostic – e.g. broken bones

(2) Therapeutic – Thyroid or bone cancer treatments

2) Consumer products and use ~ 2%

a) Smoke detectors – Americium-241

b) Cigarettes - Polonium

c) Radium dial watches and orange fiesta ware (antiques)

d) Flying and security screenings are examples

3) Industrial use ~ .1%

a) Used to measure thickness of paper, sheeting (thin materials)

b) Welding examinations (radiography)

4) Occupational

a) Working in nuclear related industries

b) About .005% of the average American's yearly exposure comes from nuclear power.

(1) This is hundred times less than the radiation exposure we receive from the use of coal for electrical generation.

(2) 200 times less than a cross-county air flight

(3) and about the same amount as that from eating one additional banana a year.

c. So on average, 600 mrem / year exposure to all forms of radiation for people in the US.

Slide 12

2. Types of Radiation

a. I will be discussing ionizing radiation, which includes the following:

1) Ioninzing means that the radiation causes electrons to be stripped from atoms (causing ion pairs)

2) Highly charged particles

3) Photons that have higher energy than light, micro waves or radio waves

b. Includes:

1) Alpha and beta particles

2) Gamma and x-rays

c. Radiation originates within the nucleus of the atom (exception is x-rays)

1) Unstable nuclei are radioactive

2) Must give off energy to achieve stability

3) Radiation is the energy emitted from radioactive materials.

Slide 13

3. Alpha radiation particles

a. Most electrically interactive

b. Least penetrating
c. Hazard only if inside the body

Slide 14

4. Beta radiation particles
   a. Not as electrically interactive as alpha particles
   b. May penetrate paper, plastic and first layer of skin (dead layer)
   c. May be hazard if enters the body, or if high energy (eyes and skin)

Slide 15

5. Gamma photons
   a. Least interactive but most penetrating
   b. A hazard to the total body, since clothing and skin would not stop
   c. Most significant hazard to radiation worker

Slide 16

6. X-rays
   a. Similar to gamma photons but of lower energy and originate in the electron shell of the atom vs. the nucleus
   b. Less penetrating than gamma photon since lower energy
   c. Most x-rays are created by man for medical purposes
   d. Hazard similar to gamma photons, if not controlled

Slide 17

7. Penetrating ability – See slide

Slide 18

8. Risks associated from Radiation Exposure
   a. Reference slide
   b. Note that medical exposure, although the highest source of man-made exposure has a lower risk due to the positive results that come from using radiation to diagnosis injury or disease and its therapeutic use for cancer.

Slide 19

9. Radiation facts or risks - Questions
   a. The majority of radiation we receive from atomic bomb testing in the 40's & 50's.

1) False – the majority of radiation we receive is from nature, next is medical exposure, followed by consumer products.
2) The highest exposure was seen in 1963, and has decreased greatly (300 times less than the peak) since then.

b. Used reactor fuel will remain radioactive forever
   1) Theoretically true
   2) However, most of the waste fuel could be used to make new fuel, if reprocessing was allowed
   3) Most of the byproducts would require long-term storage for only about 300 years
   4) Only 1% of the fuel will be at levels of great concern at the end of 10,000 years.

c. Two workers were killed at the Fukishima plant
   1) False
   2) No workers were killed by radiation exposure. Two workers received exposures over the limits (18 rem, that is 7 rem below that at which changes to blood cell counts can possibly be seen.)
   3) A few workers were killed and several injured when they drowned or were hit by falling debris. This was during the earthquake and tsunami when they were inspecting for earthquake damage outside the physical part of the plant.

d. A person exposed to x-rays will become radioactive
   1) False
   2) Radioactive material may be placed into the body for diagnostic purposes, and the radioactive material inside the person can be measured.
   3) However the radioactive material will be eventually eliminated by the body

e. Radiation exposure can cause mutations in animals
   1) Generally False for higher level mammals
   2) Four things can happen when radiation strikes the cells in our body
      a) The radiation passes through without hitting or damaging the cell
      b) The radiation hits the cell and cause some damage to the cell's contents
         (1) The cell will repair itself
         (2) This is similar to a cell being damaged by a chemical or a virus
      c) The radiation hits the cell and causes the cell to die
         (1) Similar to cells dying in our body every day.
      d) The cell is hit and repairs itself, but the DNA is damaged and the cell mutates
         (1) Mutated cells are absorbed by the body or die and are eliminated
         (2) Regarding embryos
            (a) In advanced life forms the embryo with mutated cells will usually abort early or not survive.

(b) In fact, no evidence from atomic bomb victims or radiation accidents has shown any probability of genetic mutations in humans.

(c) The most significant risk to embryos is not mutation but the increased possibility of cancer, small body growth, small head size or retardation.

Slide 20

C. Nuclear Energy Basic Operation

1. Fission Process

   a. Fissionable Uranium absorbs neutron

   b. Fission may or may not occur

   c. When fission occurs

      1) Energy within atom exceeds the binding energy of the nucleus and splits.

      2) There is a large amount of energy transferred to the fission fragments ($E=mc^2$)

      3) Additional neutrons are produced – chain reaction continues until a neutron absorber such as boron, cadmium or hafnium is inserted.

         a) Fission is controlled by controlling neutrons available to cause fission.

            (1) Temperature of the water surrounding the core (density changes allow more or less neutrons to leak out of the core and cause or not cause fission) or

            (2) Neutron absorbing materials

               (a) Boron in water to fine tune the control

               (b) Cadmium or hafnium in control rods to allow more fuel loading and to shutdown the reactor in an emergency.

         b) Use of the fuel during the life cycle of a reactor core is controlled by dilution of the boron from the water surrounding the core.

      4) The energy of the fission fragments creates heat in the fuel rodlets.

Slide 21

2. Fuel pellets and Fuel assemblies

   a. Fuel pellets are placed into stainless steel tubing to form fuel rodlets

   b. Rods are packaged into fuel assemblies

      1) About 14ft high and 10" x 10" square

   c. Heat is transferred from the fuel to the outer surface of the fuel rods.

Slide 22 & 23

   d. The heat from the rods, in direct contact with the water surrounding them, is

      1) Either used to heat water in a secondary system in PWRs, OR

2) Converted to steam and routed directly to the turbines in BWRs.

Slide 24

3) PWRs vs. BWRs
   a) Advantages
      (1) PWRs keep radioactive water separated from the steam / turbine / feedwater side
         (a) Less radiation exposure to workers
         (b) Off gases from steam cycle system are not radioactive
      (2) BWRs are a more simple design without steam generator interface that can lead to issues with corrosion and wear.
   b) Disadvantages
      (1) PWRs lose efficiency through the steam generators
      (2) Steam generator tubes have eroded and corroded if water chemistry is not controlled, foreign material issues / cleanliness issues.
      (3) BWRs
         (a) In general cause more radiation exposure per Mwe produced
         (b) Steam released during shutdown / venting is radioactive

Slide 25

e. Heat creates steam with energy that is used to drive turbine generators (This is the basic Rankine steam cycle used for many years in coal power electrical generators with boilers)
   1) Relatively old technology, but using new materials, indicators, gauges, pumps, valves, etc.
   2) Steam cycle
      a) Steam is created in the steam generator (PWR) or steam is created at the top of the reactor vessel (BWR)
      b) Steam enters the turbines through control valves
      c) Rotational energy from steam turbine turns generator connected to a common shaft
      d) Generator creates electrical current
      e) Steam is condensed back into water in condenser which is cooled by external water (Lake Michigan)
         (1) Cooling towers are used when no large supply of cold water exists
      f) Feed water is returned back to the steam generator (PWR) or reactor (BWR) for continued production of steam.
   3) PWRs / BWRs – Show flow paths on slides

Slide 26

f. PWR Major Nuclear Equipment
   1) Reactor Vessel
   2) Steam Generator

Slide 27

g. PWR Major Steam System Equipment
   1) Turbine

Slide 28

   2) Condenser
   3) Electrical
      a) Stator
      b) Rotor

Slide 29

h. Refueling Outages
   1) Completed approximately every 18 months
   2) Approximately 1/3 of core is replaced with new fuel
   3) Fuel is repositioned to use as much of the fissionable material in the assemblies as possible.
   4) Maintenance activities are accomplished and take up most of the 30-35 day outage duration.

Slide 30

D. Nuclear Waste
   1. There are three types of nuclear waste: High level, Low level, and Mill Tailings

Slide 31

   2. High Level Waste
      a. Used fuel from reactors
      b. Sources:
         1) Utilities (power reactors), Military, and Research (universities and other companies)
         2) These wastes must be controlled and are dangerous

3) Need to prevent access to the fuel for several hundreds of year

c. Electric utilities have been placing money into an escrow account kept by the US Government since around 1982.

1) Initial plan was to recycle the fuel and extract / recover the fissionable materials.

2) Vitrification of the rest of the waste would be stored long term until the radiation is essentially gone.

3) Reprocessing of the fuel was stopped in 1979 and long-term storage was proposed.

4) Approximately 700 million dollars a year are collected from utilities and their customers to this escrow account. The account is estimated to be around 27 billion dollars.

Slide 32

d. Yucca Mountain in Nevada is (was) identified and developed as a suitable storage location in 2002 and 15 billion dollars were spent making it able to receive high-level waste.

1) The NRC decided to not use the site in 2009 and it has sat idle since.

2) Currently all the used nuclear fuel in the U.S. is temporarily stored at each reactor site.

a) Temporary storage includes:

(1) Spent fuel pools (for initial cooling and radioactive decay)

(2) Dry cask (vertical and horizontal) for fuel with little residual heat and lower levels of radiation.

e. The solution to high-level waste storage is known, but the politics of the issue has lead to inaction on implementing a strategy.

1) The fuel remains stored across the nation in about 75 different locations.

2) NIMBY

Slide 33

3. Low Level Waste

a. Low level waste comes from utilities and medical uses

1) Contains waste products such as used clothing, rags, gloves, tubing, tape, glassware, etc.

2) Radioactive waste is presently buried in designated landfills in Washington state and South Carolina

a) Shallow trenches are filled and covered by several feet of soil

b) The waste is buried in the original containers in which it was shipped

b. Mill tailings are controlled locally at the site where the uranium ore was mined

1) They are covered by dirt and soil to prevent excessive release of the naturally occurring radon and thoron gases to the environment

2) Requires long term oversight

c. Regional compacts – Concept developed but not implemented

1) Wisconsin is part of the Midwest Compact

a) MN, IA, MO, IN OH and WI

b) Michigan was a member but opted out when it was selected to be the first state to host a waste site and will be responsible for only its own waste as a non-associated state.

2) Wisconsin nuclear plants, universities, hospitals and other radioactive waste producers continue to use the site at Barnwell, South Carolina or Richland, Washington.

a) As long as they will accept it.

b) Costs have increased dramatically over the last 30 years due to inability to find another location for disposal.

Slide 34

E. Nuclear Reactor Accidents

1. One to thing that must be considered in the operation of any nuclear reactor is the presence of significant amount of residual heat left in the fuel after the fission process has ceased.

a. Called "Decay heat" because it is caused by the decay of radioactive materials within the core mostly by beta radiation emission.

b. Many emergency systems, with backups, are installed to remove this heat.

c. If that heat is not removed, the core may heat up beyond the temperatures where fuel damage could occur and the radioactive materials in that fuel could be released.

2. Three Mile Island

a. Problem with the turbine (secondary) side system initiated the event

b. Inappropriate actions were taken by the operators due to:

1) A valve that was thought to be shut was stuck open

2) The operators made bad assumptions and did not believe some indications

3) Lack of adequate training

c. Results

1) Core was uncovered, decay hear was not removed and the core overheated

2) A chemical interaction of water with metal of fuel rods at high temperature creates hydrogen gas.

3) Some cracking and deterioration occurred and radioactive gases along with hydrogen gas were released to the reactor and the reactor building, through the stuck open valve.

4) Less than 12 hours after the start of the event, the hydrogen gas in the reactor building "burned"

5) Some radioactive iodine and gases were released from the reactor building (containment structure). The average exposure to the 2 million people near the plant (~320 banana doses) (I assumed that to mean within 5 - 10 miles).

6) Although long-term health effects from the release of this radioactive material have been postulated but no evidence has been observed or been statistical proven.

d. Changes made to nuclear operations

1) Improved training for operators – and others

2) Improved measurement of reactor parameters and other plant design changes

3) Improved communication to the public (Emergency planning was given a higher priority in the plant, local community and governments)

Slide 35

3. Chernobyl – Ukraine 1986

a. Initiated by the deviation from an approved test procedure

1) Actions caused a steam explosion

2) Dispersed graphite core to environment (no containment structure)

b. Cause of extreme radioactive material release to environment

1) Core design (positive temperature coefficient)

2) No containment building

3) Results

a) 28 deaths to initial responders (fire fighters mostly) and operators who were in the area of the reactor building

b) 230 workers involved with the clean up had signs of acute radiation sickness

c) An increase in cancer related deaths to the surrounding population was speculated to be around 4,000

(1) However, only 10 cancer-related deaths have been verified and reported from radiation exposure since the accident.

(2) Most of these deaths have been from thyroid cancer.

c. Actions taken in response to this accident

1) Improved procedure use and adherence

2) Improved respect for the energy that is in the core

Slide 36

4. Fukishima

a. Initiated by the tsunami that stuck the plant after the earthquake

1) The plant responded as designed to the earthquake with minimum damage to the equipment.
2) Tsunami exceeded the design parameters for the plant (wave exceeded19 ft)
3) Plant is an older design
    a) Placement of emergency backup electrical power supplies were in basement and lower levels by design
        (1) Protect from outside attacks – planes, bombs, etc.
        (2) Protect from weather related damage – tornados, hurricanes
4) Loss of surrounding area infrastructure delayed ability to cool reactor
    a) Electrical power
    b) Resources to assist

Slide 37

5. Fukishima – Accident sequence
    a. Earthquake hit plant and units were shutdown
    b. Tsunami hit plant about 50 minutes after the earthquake
    c. Flooded the compartments that held the emergency electric diesel generators
    d. Cooling of core continued for about 8 hours until batteries died
    e. Pressure built up inside the reactor and needed to be released to save the integrity of the Rx vessel.
        1) Some hydrogen gas built up in the steam inside the reactor due to high temperature of fuel (Zr-$H_2$0 reaction)
        2) Steam released to torus was radioactive and had hydrogen in it.
            a) Hydrogen and radioactive materials came out of solution in torus
            b) Leaks in torus due to earthquake rose to highest level in support building
        3) A motor starting or static electricity probably ignited the hydrogen gas that escaped into the support building above the reactor.
    f. The explosions seen in pictures during the event are the hydrogen gases burning rapidly in the area above the reactor.
        1) Core did not explode
        2) Major radioactive materials was kept within the containment structure
        3) Releases came from gaseous radioactive materials
            a) Iodine, Noble gases and daughter products
    g. Actions taken in response to accident
        1) Evaluation of seismic and flooding issues
        2) Improvement of procedures to respond to accidents beyond design basis
            a) Loss of all power

b) Severe accident management guidelines

3) Improvement of emergency planning organizations to notify, relocate and protect people and the environment

4) Improvements in measuring parameters of spent fuel stored in on-site pools

h. Reassessment of future nuclear power use in many countries.

Slide 38

F. Future Use of Nuclear Power

1. Types of Reactors

a. Approved large-scale PWRs and BWRs

1) Advanced designs

2) Safer and more efficient operation

3) Refer back to slide on new construction

b. Small Nuclear Reactors (SNRs)

1) Approximately 350 Mwe

2) Factory built – modular

3) Lower cost – TBD

4) Cores similar to submarine design

c. Fusion Reactors

1) International Thermonuclear Experimental Reactor (ITER)

a) Developing experimental fusion reactor to demonstrate feasibility

b) Located in southern France

c) Consortium of nations (UK, Russia, India, China, US, France)

Slide 39

2. Cost of alternatives vs. nuclear power

a. Estimated costs based upon ability of producing one trillion kWhrs over the lifetime of the plant or infrastructure

b. Includes site preparation, construction, support equipment, operation and maintenance of facility

1) Hydro = 3.3 cents

2) Nuclear = 3.5 cents

3) Natural gas = 3.7 cents @ $2.60 per mcf (million cubic feet)

4) Coal = 4.1 cents

5) Wind = 4.3 cents

6) Natural gas = 5.1 cents @ $4.00/mcf

7) Solar = 7 cents

c. Price of natural gas expected to be most volatile with prices rising in mid century

3. Other considerations

a. Land use

b. Waste Disposal

c. Carbon footprint

d. Risk

Slide 40

III. Summary

A. Questions

B. Thanks for your attention

C. If you'd like a similar talk for your group contact me