Earthquake and the Fukushima-Daiichi Nuclear Reactors in Japan

Dr. Danon

Physics of Nuclear Reactors, March 21, 2011
What do we know?

- All the information we have is from the media.
- More reliable; nuclear related information:
  - www.nei.org
  - www.iaea.org
- THE REST IS INTERPRETATION OF THIS DATA
BWR Reactor (Mark I containment)

Boiling Water Reactor Design
At Fukushima Daiichi

Secondary Containment:
Area of Explosion
At Fukushima Daiichi
Units 1 and 3

Steel Containment Vessel

Primary Containment

Spent Fuel Pool

Reactor Vessel

Suppression Pool (Torus)

Seawater is being pumped into Reactor Vessels at Units 1, 2 and 3

Updated 3/17/11
BWR containment in more detail

- Mark I suppression pool is located in the steel torus shaped ring below the reactor vessel
- The function of the suppression pool is to condense steam from the reactor vessel during emergency conditions
Time line (speculated)

- A ~9 on a Richter earthquake hit the east cost of Japan
- Reactors 1,2 and 3 automatically shut down
  - The closed-loop residual heat removal (RHR) system started to cool the reactor (decay heat power is ~3%-7% of full power).
  - Units 4,5,6 were already shut down (might have had problem with spent fuel pool)
- Tsunami hits the reactors
  - Diesel generators stop working (powers RHR)
  - Battery backup started and lasts ~8 hours
- RHR stops and water in the pressure vessel boils.
  - Exposed Zr oxidizes \( (\text{Zr} + 2\text{H}_2\text{O} = \text{ZrO}_2 + 2\text{H}_2) \) producing hydrogen
Explosion of the reactor building

- To keep cooling the core sea water was used
  - In order to inject sea water into the reactor pressure vessel (RPV), and to prevent over pressure the RPV was vented.
  - The core is vented through the containment to the rector building
- When the core is vented, hydrogen reacts with oxygen and explodes
  - The roof and wall of the reactor building were destroyed.
  - Some radioactive (fission) products were released and detected by area monitors.
    - This can indicate some damage to the fuel (due to high heat)
- Radiation level drops after the venting
  - The containment is apparently intact.
Fire in spent fuel pools (Reactors 4 & 3)

- On 3/14/2011 fire started in the spent fuel pool of reactor 4
  - Japanese claim oil fire
  - Radiation level increase in the pool vicinity
  - Possible radioactivity release
    - This might indicate Zr fire or damaged fuel cladding
- Water in pool drops exposing the fuel and thus increasing the radiation level
  - Prevents works from cooling the reactor
  - The pool normally has at least 16 ft of water above the fuel, so evaporation is slow
- Pool keeps losing water
  - Possible crack in the pool
How to achieve stability

- Cool the spent fuel pools by restoring the water level
  - Need constant flow of water
  - It will lower the radiation levels and allow workers to get closer.
- Restore electricity to the plant
  - Enable RHR on cores
- Maintain cooling and plan cleanup
Put it in Perspective

- As result of the earthquake more than 8000 are dead
- **So far** only one worker died as result of the events at the Fukushima reactor. (due to explosion not radiation)
- Reactor workers were injured from the explosions and were exposed to radiation (not clear how many).
- Radiation release to the population is small and not expected to have significant impact on public health
  - It can be compared to a CT scan or several flights.
What should you do?

• Educate yourself on the issue
  • Know the facts
  • Visit the sites I mentioned
• Discuss this with other people (don’t argue)
  • We can not give up nuclear power, we need it as part of a diversified energy portfolio
  • Nuclear power is safe and reliable source of (large quantities of) energy
• This is still a fluid event and we need to wait before we draw final conclusions.
• Learn what can be done to improve reactor safety:
  • Read about generation III+ designs with passive cooling (AP1000 for example)
  • Read about “core catcher” design for the EPR reactor