The Evolution of Nuclear Safety
What have we learned from Fukushima?

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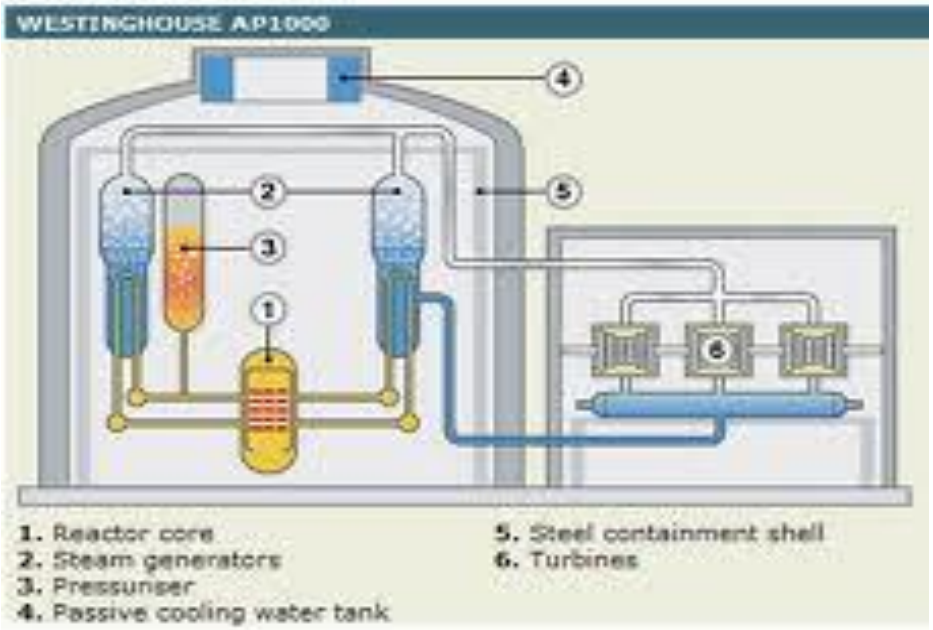
Purpose of my Presentation

- Explain how the nuclear industry improves safety
- Point out some of the key things happened during the Fukushima accident.
- Help the general public understand more of the important findings from the accident.
- Hope the public will transform these new understanding into a renewed confidence in nuclear power, particularly in Taiwan.

Nuclear Power Plant

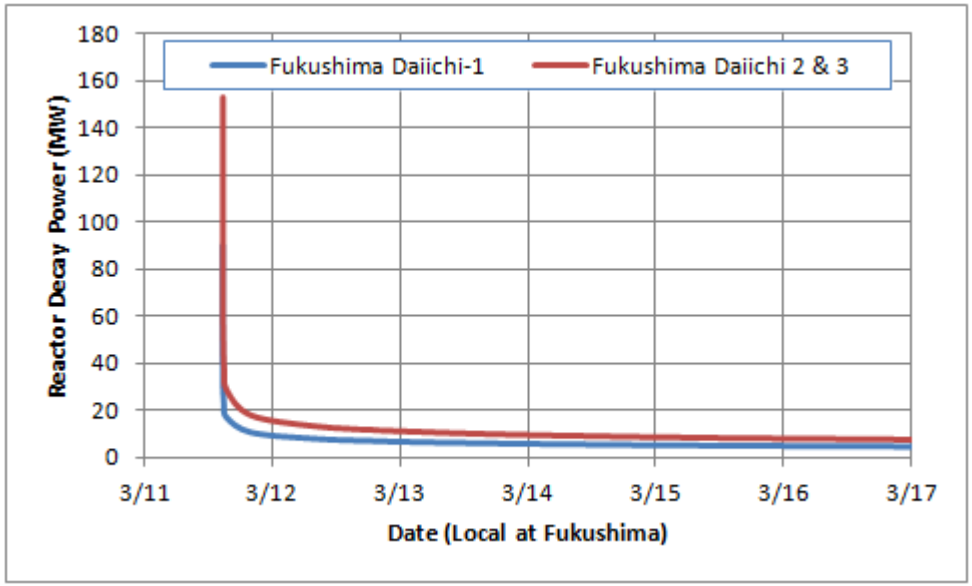


Reactor type: PWR
Generation capacity: 1,117 MW
Design life: 60 years
Construction time: 36 months
Manufacturer: US-based Westinghouse

Nuclear Fuel Element

Source: Babcock and Wilcox Company

Decay Heat


Fukushima Daiichi-1
Fukushima Daiichi 2 & 3
Reactor Decay Power (MW)
180
160
140
120
100
80
60
40
20
0
3/11
3/12
3/13
3/14
3/15
3/16
3/17
Date (Local at Fukushima)

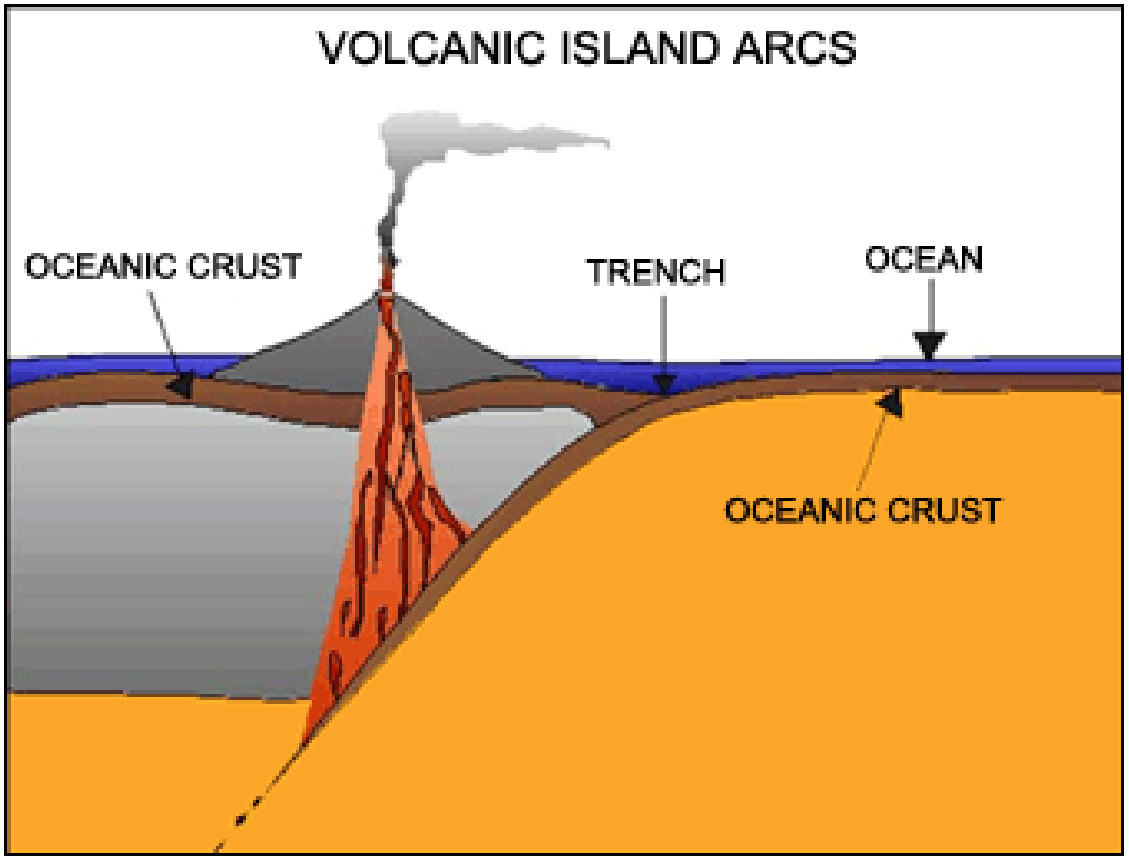
How Much Water is Needed?

- I estimated that, 10 hours after reactor scram we need to supply about 80 gallons/min of water to cool the fuel in the reactor core (by boiling off the decay heat).
- 2 days after reactor scram it goes down to about 30-40 gallons/min…..then it goes down slowly…over a few months later we still need to supply about 10 gallons/min….
- If this can be provided to the core continuously and keep the core submerged in water there will be no meltdown and no massive release of radioactive material….The public will be protected…
- This is really not a lot of water……Well within the capability of a fire truck…..A garden hose can supply about 2 gallons/min…

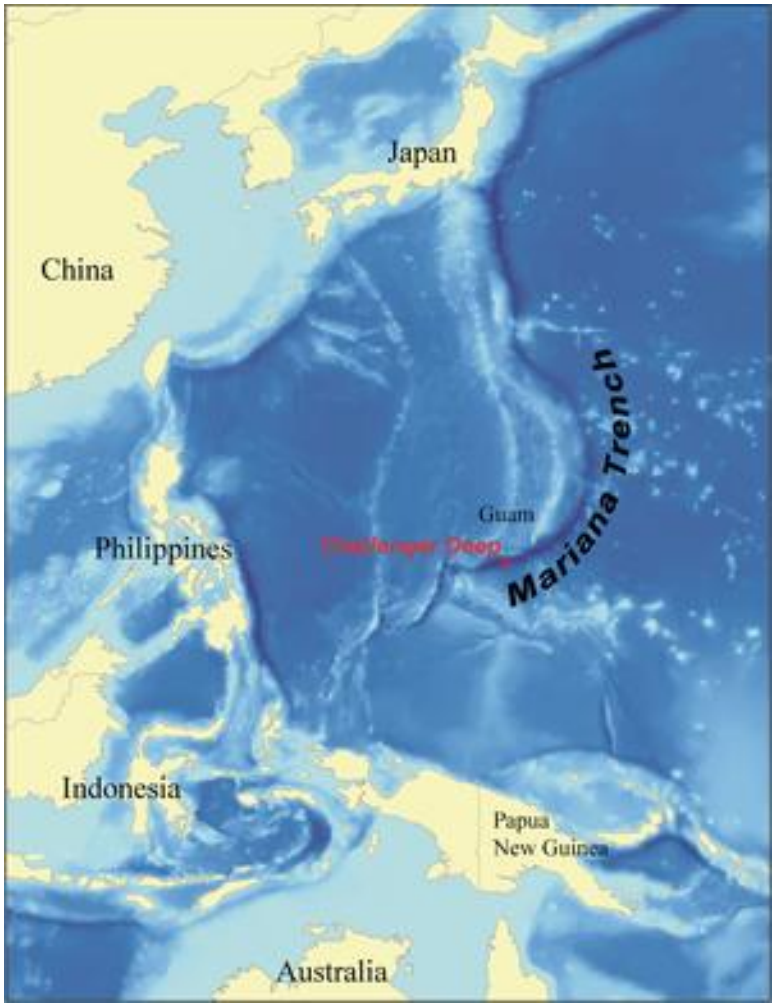
Fukushima

- 9.0 earthquake on the Richter scale
- Subduction Zone Earthquake
- 14 meters high Tsunami..
- All emergency diesel generators lost, even DC power was lost, total station blackout…
- Reactor core meltdown,
- Hydrogen Explosions
- Large scale release of radioactive material to the environment.
- Public lost confidence in nuclear power…
- In Taiwan, people are genuinely scared and understandably concerned. Some wanted to stop construction of NP4, a 2 unit plant near the end of construction. The government is setting up a referendum allowing the people to decide whether to continue construction or scrap the plant.
- If the public know more about the accident they may think differently….Let the fact speaks for itself…

Subduction Zone Earthquake



Mariana Trench



Accident Timeline

- Units 1,2,3 in normal full power operation, other units off line
- March 11, 2011 at 14:46 earthquake hit
- Units 1,2,3 all SCRAM, emergency diesels start, shutdown cooling in progress, everything normal…
- 51 min from quake, tsunami hit, total loss of electrical power, cooling interrupted,….
- 3 hour 13 min from tsunami, unit 1, show core damage…

Accident Timeline

- 14 hours from tsunami, unit 1 start freshwater injection,
- 24 hours from tsunami, unit 1, hydrogen explosion
- 27 hours from tsunami, unit 1, start sea water injection
- 43 hours from tsunami, unit 3 core damage，soon followed by its own Hydrogen explosion, then sea water injection
- 76 hours from tsunami, unit 2 core damage, then sea water injection

Fukushima Accident

- Earthquake + Tsunami of this magnitude could happen only at a few places in the world,… Japan's east coast,…deep trench,…Entire continent of Japan moved eastward by 8 feet during this earthquake…
- Earthquake magnitude exceeded plant design basis
- Safety structure needed for cooldown mostly held together, most system function remain intact, may have a minor small LOCA in unit 1,… lost of all safety related electrical power (AC & DC),
- Accident considered preventable… massive release could have been avoided…human error was the cause for the disaster…concluded in a report….

Fukushima Accident

- The Japanese legislative body, the National Diet, established a Fukushima Accident Independent Investigation Commission. Performed a comprehensive investigation and published a report…
- Revealed significant shortcomings; with many organizational issues, management/chain of command issues, cozy relationship between the regulator and the utility, lack of implementation of facility upgrades to meet internationally accepted standards….regulatory system failure…

Fukushima Accident

- Report concludes that, this nuclear accident was “Preventable”…
- Accident cannot be blamed on earthquake, tsunami, loss of all electrical power in the plant….
- They blamed it on human error, failure to implement changes required by international standard….
- Large scale of releases could have been avoided…
- The public could have been protected…

Most people automatically assume the following;

- If it happens in Japan it could happen in Taiwan or in any reactor…
- 9.0 earthquake exceeded design specification…..
- 14 meter tsunami exceeded the design spec (5-meters)….
- Total loss of electrical power, not anticipated, exceeded design spec….The plant does not stand a chance….
- Plant staff, everybody (onsite and offsite) did the best job they could…what they did during accident made no difference to the outcome…
- There was no way to prevent the nuclear disaster from happening…
- The old plant simply cannot survive this kind of natural phenomenon event…..It was simply too severe….
- Massive release of radioactive material unavoidable…we can't help it…
- Was this the case or not?….No….

Fukushima Accident

- The report concludes, using their own words, “What must be admitted – very painfully – is that this was a disaster “Made in Japan.” Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to ‘sticking with the program’; our groupism; and our insularity caused the accident”

中文注解

我們的問題是；

- 對上級盲目的服從， 對長官的意見從不質疑，做事固守成規，團隊精神至上，跳不出一個島國的閉鎖心態。

How do we solve the problem?

- Identify all the things that should have been done and did not get done “before” the accident and find out why…Things that could have made a difference to the outcome of the accident…
- Identify all the things that could have been done and did not get done “during” the accident and find out why…
- These all sounded like a witch hunt…or Monday morning quarterbacking…but it really needs to be done….stick to the facts…stay out of name calling…interview all the people involved….apply problem solving techniques….perform engineering/technical analysis….work the issues to death….
- Prepare report to document the findings, come up with the recommendations, address the priorities,….
- Example; Investigate operator’s actions during accident….what should have been done?...why it did not get done?....what was the constraints?....what was lacking?.....how to make it happen?.....

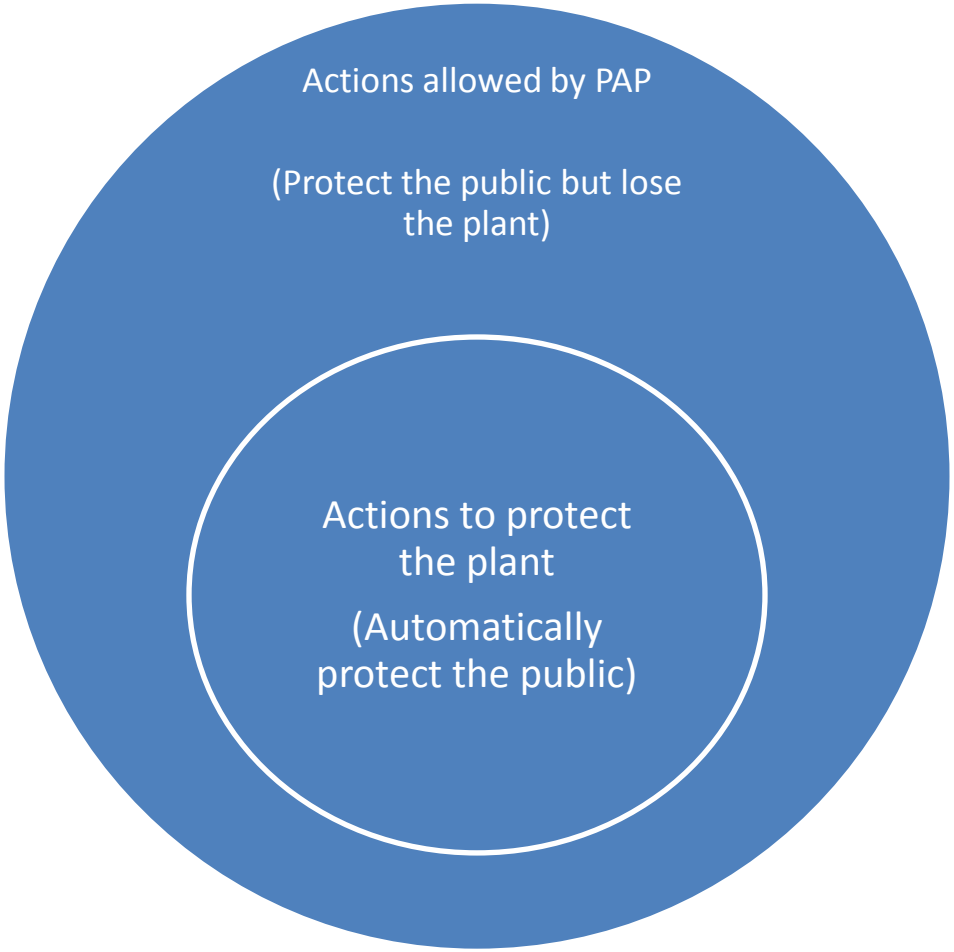
Critique the Operator Actions

- Report focused too much on plant modifications that should have been done and cannot be done easily before the accident……lead readers to believe the public is doomed…
- Very little coverage on the operators response during the critical time period between tsunami hit and up to the onset of core damage……valuable time was lost…
- I believe the accident is survivable if operator is authorized to timely activate the PAP…
- The report does acknowledge that the plant cannot be saved (return to power operation) when there is a total loss of electrical power…to me this means PAP should have been activated to save the public……massive release can be prevented…
- The timeline indicates the injection of sea water following discovery of core damage in units 1, 2, and 3….This, to me, means they have already hooked up the connection from the sea to the core and are waiting for the core damage to occur then begin pumping sea water into the core……Totally unacceptable operator response …another clear indication that the massive release could have been avoided by proper operator response….
- “Human error” was blamed as the cause for the accident but, if you blame everybody, then no body is to shoulder the responsibility, especially if you blame it on the “Japanese culture” as the problem…….Not sure who can fix that and how?.....

Plant Abandonment Procedure (PAP)

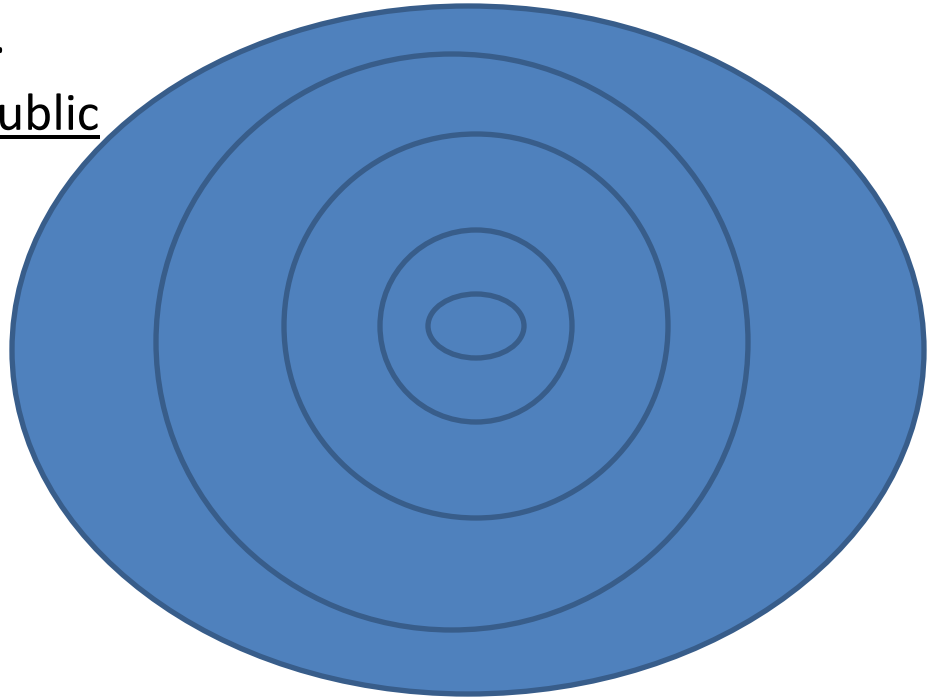
- Fukushima timeline clearly showed PAP is needed….
- Operators should be instructed to recognize the condition and timely activate the PAP to protect the public (forget about saving the plant, focus on saving the public under the severe accident conditions)…
- Management and operational staff should be giving the authority to act.
- Just what are the kind of things they need to do when PAP is activated?…

Operator Actions During Emergency



Essential Equipment Needed for Cooldown

- Normal operation needs all equipment…
- Normal cooldown, no venting, need less but quite a lot of equipment…
- Allow venting needs less equipment but, small radioactive release…
- Faster cooldown needs even less equipment…
- PAP needs much less equipment….
- PAP loses the plant, protects the public



Operator Actions (normal shutdown/cooldown)

- To protect the plant; operators are allowed only using very clean water to cool the nuclear fuel (demineralized water)
- They also must observe proper cooldown and depressurizaion limits to protect the reactor vessel and the components within…
- No venting of radioactive steam into the environment.
- Slow and orderly shutdown/cooldown…require more equipment and electrical power (cannot be done on a station black out situation)…

Operator Actions
(In a Severe Accident when PAP is Activated)

- Fast depressurization to facilitate water injection.
- Venting radioactive steam into environment if necessary to achieve the depressurization….small release vs massive release….
- Use any source of water available, demin-water, raw water, fire water, river water, sea water…
- Use any power source available to achieve water injection into the core...
- Goal is to always keep the core covered…
- Time is of essence in this case, water injection into the core must be resumed within a few hours from total loss of station electrical power to avoid core damage.
- Must mobilize onsite and offsite supports to achieve this goal.

How to Implement the PAP

- Need actions from the regulator, the reactor designer, the plant operation staff, and the offsite support units,
- The regulator needs to establish the regulatory requirements,
- The reactor designer needs to come up with new guideline for operational limits under the severe accident conditions and hardware modifications to facilitate water injection…
- The operation staff needs to be trained and empowered with the authority to act,….
- New procedures must be in place…
- Offsite support from local government, the military, the emergency responders…

Bottom Line

- This process to improve nuclear safety is alive and working very well. We should continue improve nuclear safety by learning the lessons from accidents and implement all necessary changes…
- Remember, 9.0 earthquake + 14 meter tsunami + station black out, as bad as it is, does NOT automatically = massive release of radioactive material ….
- Remember, the design limits may have been exceeded there are still things operators can do to prevent core meltdown and, prevent massive release of radioactive material… It was not hopeless… As severe as it is, this accident is survivable…
- Remember, this was a big accident, we learn the lesson, we will prevent similar accidents from happening again in the future…. Now we know how to handle this one, safety of all nuclear plants has moved a bid step forward….
- I hope the public can take some comfort in this and… re-establish their confidence in nuclear safety….support the continued use of nuclear power,… Like to send an important message to the people in Taiwan,.. Vote for the continued construction of NP4 in the upcoming referendum.

結　論

- 從意外事故學取教訓，改進核能電廠抗災的能力是促進核能安全的最佳途徑。這套方式行之已久，成效豐碩，值得宣揚。
- 福島核災很清楚告訴我們，雖然地震海嘯都嚴重超過設計指標，受傷的電廠還是有能力保護大眾。如果建立廢廠機制，適時啟動，可以做到避免電廠核心受損，防止放射物質外泄。不會傷害周圍居民與環境。避開福島電廠目前面對的慘況。
- 這是我們從福島核災學到的經驗，跟大家分享。預防類似的核災發生，已經有對策，將來這種情況不會再發生，臺灣已經吸取到福島的教訓，核能電廠操作人員都已經知道如何應付。不需要花費很多的資源與人力就能有效解決問題，希望民眾明察真相，排除恐懼，恢復對核能安全的信心，繼續安心使用核能，踴躍參加公投，贊成核四續建。

Thank you and, Good Evening

Questions….