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Helicopters Dropping Water on Affected Reactors

Posted on March 17, 2011 12:30 am UTC by mitnse

UPDATE AS OF 9:00 P.M. EDT, WEDNESDAY, MARCH 16:

Crews began aerial water spraying operations from helicopters to cool reactor 3 at Fukushima Daiichi shortly before 9 p.m. EDT on Wednesday, March 16. The operation was planned for the previous day, but was postponed because of high radiation levels at the plant. News sources said temperatures at reactor 3 were rising. Each helicopter is capable of releasing 7.5 tons of water.

Spokesmen for TEPCO and Japan's regulatory agency, Nuclear and Industry Safety Agency, on March 17 Japan time refuted reports that there was a complete loss of cooling water in the used fuel pool at Fukushima Daiichi reactor 4.

The spokesmen said the situation at reactor 4 has changed little during the day today and water remained in the fuel pool. However, both officials said that the reactor had not been inspected in recent hours.

"We can't get inside to check, but we've been carefully watching the building's environs, and there has not been any particular problem," said TEPCO spokesman Hajime Motojuku.

At about 7 p.m. EDT, NISA spokesman Takumi Koyamada said the temperature reading from the used fuel pool on Wednesday was 84 degrees Celsius and that no change had been reported since then. Typically, used uranium fuel rods are stored in deep water pools at temperatures of about 30 degrees Celsius.

Recent radiation levels measured at the boundary of the Fukushima Daiichi plant have been dropping steadily over the past 12 hours, Japan's Nuclear and Industrial Safety Agency said on Wednesday night (U.S. time).

At 4 a.m. EDT on Wednesday, a radiation level of 75 millirem per hour was recorded at the plant's main gate. At 4 p.m. EDT, the reading at one plant site gate was 34 millirem per hour. By comparison, the Nuclear Regulatory Commission's annual radiation dose limit for the public is 100 millirem. Radiation readings are being taken every 30 minutes.

Japan's Chief Cabinet Secretary, Yukio Edano, said earlier today a radiation level of 33 millirem per hour was measured about 20 kilometers from the Fukushima Daiichi plant earlier this morning. He said that level does not pose an immediate health risk.

Edano said that TEPCO has resumed efforts to spray water into the used fuel pool at the damaged reactor 4.

TEPCO also continues efforts to restore offsite power to the plant, with up to 40 workers seeking to restore electricity to essential plant systems by Thursday morning, March 17.

http://nei.cachefly.net/newsandevents/information-on-the-japanese-earthquake-and-reactors-in-that-region/

The Wall Street Journal confirms the report, but suggests an external power line will be connected on Thursday afternoon (local time).

http://online.wsj.com/article/SB10001424052748704261504576205363484153564.html

Posted in Uncategorized | Comments Off

Introduction to Radiation Health Effects and Radiation Status at Fukushima

Posted on March 16, 2011 11:39 pm UTC by mitnse

What is radiation? Where does it come from and what is it used for?

Radiation is energy that propagates through matter or space. Radiation energy can be electromagnetic or particulate. Radiation is usually classified into non-ionizing (visible light, TV, radio wave) and ionizing radiation. Ionizing radiation has the ability to knock electrons off of atoms, changing its chemical properties. This process is referred to ionization (hence the name, ionizing radiation). Ionizing radiation is the main concern for health effects since it can change chemicals' properties in the human body.

Radiation comes from many sources including cosmic rays from the universe, the earth, as well as man-made sources such as those from nuclear fuel and medical procedures. Radiation has been used in many industries including diagnostic imaging, cancer treatment (such as radiation therapy), nuclear reactors with neutron fission, radioactive dating of objects (carbon dating), as well as material analysis.

Ionizing radiation and its effects on the human body

There are four main types of ionizing radiation: electrons (also known as beta), photons (mostly gamma ray and X-ray), charged particles (alpha) and neutrons. In a nuclear reactor, the radiation is formed due to the decay of radioactive isotopes, which are produced as part of nuclear reactions inside the reactor.

Each ionizing radiation type interacts with the body differently but the end results are similar. When radiation enters a body, it can deposit enough energy that can directly damage DNA or cause many ionizations of atoms in tissues that would eventually cause damage to critical chemical bonds in the body. The mechanisms of how radiation damages tissues and the degree of damage of each type of radiation are different. However, the amount of radiation needed to cause permanent damage to the tissue depends on the total dose to the body, the type of radiation, and the amount of time it takes to get that amount of radiation (dose rate). Also, depending on the total dose and/or dose rate, the effect can be acute (happen right away such as radiation burns, sickness, nausea) or delayed (long-term, such as cancer).

What are the health effects of various doses/dose rates?

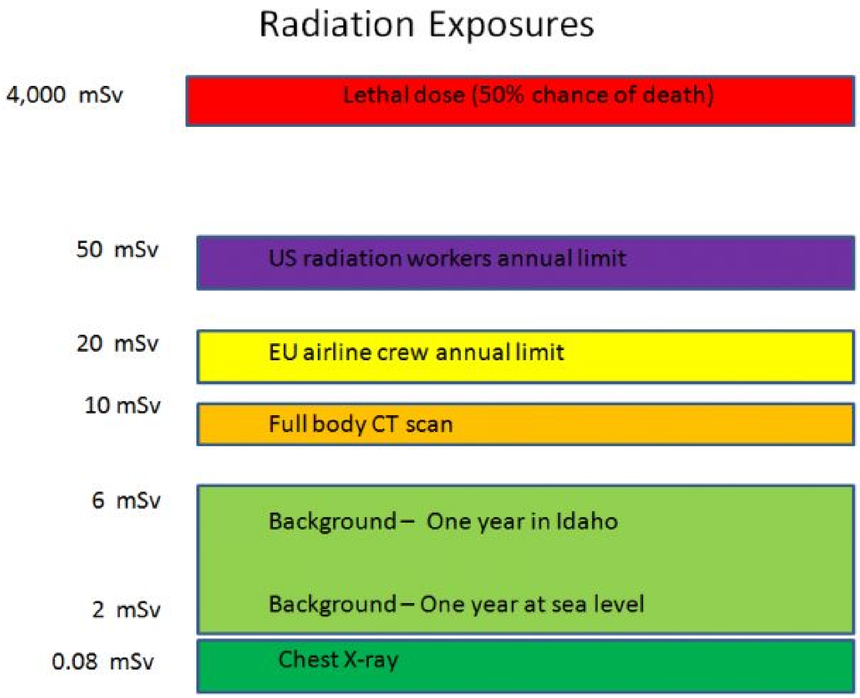
Radiation dose is measured in Rad or Gy (1Gy = 100 Rad). However, the most often reported two units that have been mentioned in the media are Sievert (Sv) and Rem (1 Sv = 100 Rem). These are defined as dose equivalent, which accounts for the different effects each type of radiation have on the body. The Sievert and Rem are units used by regulatory authorities to control radiation release and exposure. The table below lists the different amount of radiation you can get from your normal activities.

Source of Radiation	**Dose/ Dose Rate in millirem (mrem)**	**Dose/Dose Rate in milliSv**
Background (average in U.S.)	~360 millirem per year (1 millirem per day)	3.6 milliSievert

Chest X-ray	~8 millirem per X-ray	.08 milliSievert
CT scan of abdomen	~800 millirem	8 milliSievert
A cross country flight in the U.S.	2-5 millirem	0.02 - 0.05 milliSievert
Regulatory limit for radiation workers	5000 millirem per year	50 milliSievert

note: 1 Rem = 1000 millirem; 1Sv = 1000 millisievert

It is important to note that the health effects of radiation exposure vary for different doses. It is important to note dose is different from dose rate. Dose refers to the total amount of exposure, while dose rate refers to the exposure per unit of time (typically per hour). The dose numbers provided in the following discussion are not exact numbers, but instead general averages. An acute dose (received in a few days) above 250-400 Rem (2.5 – 4.0 Sv) is considered to be lethal for at least half of the population exposed. Not much is known about doses between 50 Rem and 250 Rem (500 mSv and 2500 mSv), but the exposed person will experience acute radiation sickness. The symptoms of such exposure can include nausea, vomiting, diarrhea, burns, and hair loss, but may or may not lead to near term death. Below this level, no acute symptoms have been observed. For radiation exposure of less than 50 Rem there is the potential for delayed effects such as non-specific life shortening, genetic effects, fetal effects, and cancer, but little is known about the long term consequences of exposures in this range. For doses less than 25 Rem there are not enough data to determine if such an exposure can cause any long-term effects on human health at all.



Lethal radiation dose compared to dose from normal activities. Again, these numbers reflect cumulative dose, not dose rates. To determine cumulative dose, multiply the dose rate by the time exposed:

Cumulative Dose = Dose Rate x Time Exposed

Radiation released from reactors at Fukushima and what it means

The radioactive fission products from the affected reactors include noble gases (xenon and krypton), volatile radioactive isotopes (iodine-131 and cesium-137) and non-volatile fission products. As mentioned before, these radioactive products release radiation as they decay. Therefore, over exposure and/or contact with them is dangerous. The noble gases are usually not of a big concern since they are inert, and tend to impose very small doses. Non-volatile fission products usually stay within the fuels so that is not much of a concern to the general public either. The fission products of most concern are the volatile ones such as I-131 and Cs-137 since they can be dispersed in air and get carried far away by wind from the affected reactors.

Iodine-131 is a radioactive isotope that releases beta particles (electrons). Concentration of iodine-131 in the thyroid has been shown to cause thyroid cancer. Therefore, it is a big concern if too much iodine-131 gets out of the reactor and falls to the ground away from the affected reactors. This can contaminate food, water, and animal products such as milk. The Japanese government has distributed iodine pills to people in the affected area. These iodine pills contain stable iodine-127, which does not cause cancer. When people take these iodine pills their bodies absorb the stable iodine to a level that prevents or limits the absorption of I-131, which helps to prevent the risk of thyroid cancer. Another fact about radioactive iodine-131 is that its half-life (the time it take for half of it to decay to stability) is only about 8 days. This means that after about three months, almost all of the radioactive iodine-131 would have decayed away.

Cs-137, also emits a beta particle as it decays. Exposure to Cs-137 can also increase the risk of getting cancer but that again depends on the dose and the dose rate. However, Cs-137 causes a much longer term contamination problem because its half-life is about 30 years. Depending on the amount of Cs-137 that is released, and the regulations for acceptable elevated background radiation levels, the area contaminated with Cs-137 may not be inhabitable for a long time.

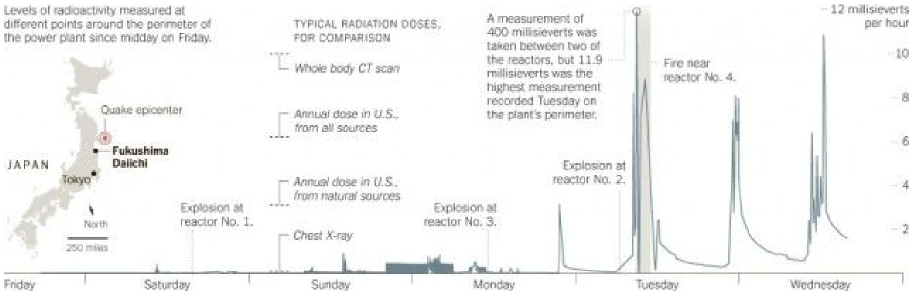
How to minimize radiation exposure

The rules of thumb for minimizing your exposure are to use time, distance, and shielding to your advantage. Shorten the time of your exposure to radiation, stay as far away from the radioactive source as reasonably possible (radiation goes down quickly as a function of distance, $\sim 1/r^2$), and provide more shielding between you and the source. This is one of the reasons the people very close to the reactors were required to evacuate very early on after the earthquake. Also, the government recommended people between 20 and 30 km to stay indoors (because their houses provide extra shielding from some of the radiation – beta, alpha), and minimize their time outdoors to limit their exposure.

We strongly urge that our readers in the region follow the instructions of their local governments regarding if, when, and how to take cover or evacuate.

Radiation dose rate history at the Fukushima Daiichi site perimeter

The figure below was taken from the NY Times on 3/16/11:



http://www.nytimes.com/interactive/2011/03/16/world/asia/20110316-japan-quake-radiation.html?ref=asia

Posted in radiation effects | Comments Off

News Updates and Current Status of Facilities

Posted on March 16, 2011 10:59 am UTC by mitnse

Units 1 and 2: TEPCO has released estimates of the levels of core damage at these two reactors: 70% damage at Unit 1 and 33% at Unit 2. They have also stated that Unit 1 is being adequately cooled.

Outlook: It is difficult to make conjectures at this point about the final disposition of the damaged fuel without further information. However, during our only operating experience with a partially melted and subsequently cooled core, Three Mile Island, the fuel mass was fully contained by the reactor vessel, resulting in minimal radiation release to the public. A decision is currently being made on how to best supply cooling water to Unit 2.

Unit 3: At 8:34 AM JST, white smoke was seen billowing from the roof of Unit 3. The source of this smoke was not investigated because workers were evacuated due to radiation levels. These levels had been fluctuating during the early morning hours before rising to 300-400 millisievert/hr around the time that the smoke appeared. It was unclear at the time whether these rising levels were a result of some new event at Unit 3, or were lingering as a result of Unit 2's recent troubles.

Outlook: In order to provide some perspective on worker doses to this point, radiation sickness sets in at roughly 1000 millisieverts. A future post will deal further with the health effects of various amounts of radiation. Response to the smoke seen at Unit 3 appears to be in an information gathering phase at this point. Chief Cabinet Secretary Yukio Edano speculated that the smoke from Unit 3 might be the result of a similar wetwell explosion to that at Unit 2, but there is not enough information currently available to support or refute that statement.

Units 4-6: Flames at Unit 4 were reported to be the result of a pump fire, which caused a small explosion that damaged the roof of Unit 4 (See TEPCO's press release on the most recent fire at http://www.tepco.co.jp/en/press/corp-com/release/11031606-e.html) . Efforts at Units 4-6 are focused on supplying cooling water to the spent fuel storage pools. Temperatures in these pools began to rise in the days after the quake. At the time of the quake, only Unit 4's core had been fully offloaded to the spent fuel pool for maintenance; roughly 1/3 of the cores of Units 5 and 6 had been offloaded. This explains in part why the temperature in Unit 4's pool has risen faster than at the other reactors: it has a higher inventory, both in fuel volume and in heat load.

Outlook: The fuel within these pools needs to remain covered with cooling water in order to prevent the low levels of decay heat present from causing it to melt, and also in order to provide shielding. Boiling of the water results in reduction of the water level in the pools, so if/when the pools get hot enough for boiling to begin, water needs to be added to replace what boils off. The staff of Unit 4 plan to begin pumping water to the spent fuel pool from ground level as soon as radiation levels from Unit 3 are low enough for them to return. This pumping operation should be relatively easier than injection of cooling water into the reactor vessels at Units 1-3 because the pools are at atmospheric pressure.

Sources: TEPCO, World Nuclear News

UPDATE (11:48 AM EST): A report by the Federation of Electric Power Companies of Japan indicates that radiation levels as a result of the Unit 4 fire were higher than those reported previously. Radiation levels early this morning at the outside of Unit 3 measured at 400 millisieverts/hr. At the present time however, radiation levels at the boundary of the facility are 1530 microsieverts/hour. We will continue to update as further reliable information is available.

Posted in Uncategorized | 2 Comments

What is Decay Heat?

Posted on March 16, 2011 7:01 am UTC by mitnse

Explanation of Nuclear Reactor Decay Heat

Nuclear reactors produce electricity in a similar way to conventional coal plants in that they heat steam to drive a turbine that spins an electric generator. However, they differ on how that heat is produced. Coal plants burn coal to heat a boiler that produces the steam while nuclear reactors use nuclear fission to create the heat. The Fukushima reactors are boiling water reactors (BWRs) that produce the steam directly in the reactor core, which then drives the turbines.

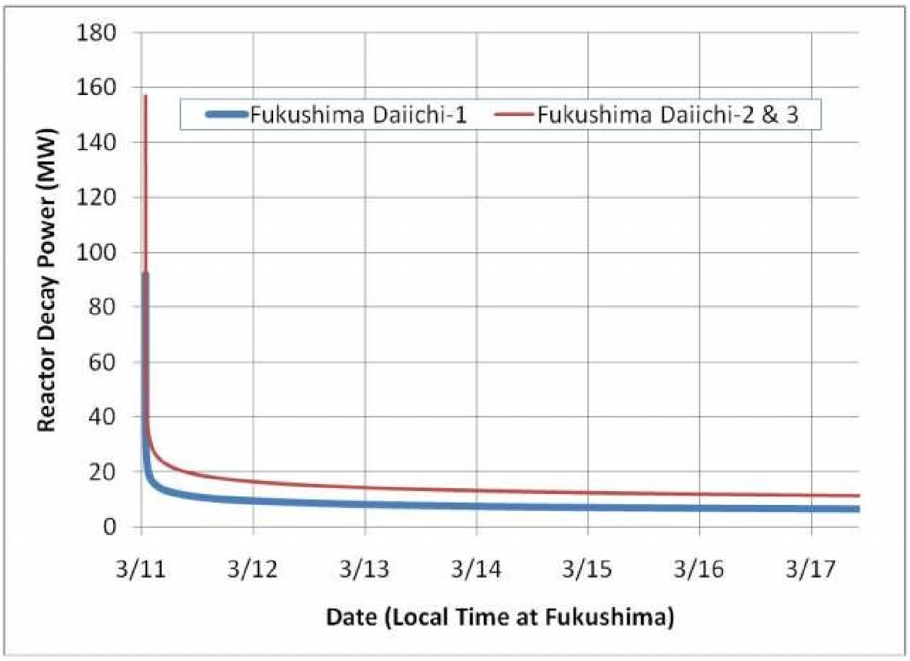
The heat in an operating reactor is produced mainly by the fission of fissile isotopes such as uranium-235 and plutonium-239. When a neutron causes one of these isotopes to split, a large amount of energy is released, which is then deposited in the fuel, cladding, coolant, and structures. On average, approximately 80% of the energy released in a fission reaction is imparted to the two or more fission products and these deposit their energy in the fuel since they have a very short range. The rest of the energy is released in the form of neutrons, and other forms of radiation.

When there is a SCRAM, where all the control rods are inserted and the reactor is shutdown, the fission reactions essentially stop and the power drops drastically to about 7% of full power in 1 second. The power does not drop to zero because of the radioactive isotopes that remain from the prior fissioning of the fuel. These radioactive isotopes, also called fission products, continue to produce various types of radiation as they decay, such as gamma rays, beta particles, and alpha particles. The decay radiation then deposits most of its energy in the fuel, and this is what is referred to as decay heat. As these radioactive isotopes continue to decay, more and more of them reach a stable state and stop emitting radiation, and thus no longer contribute to the decay heat.

The decay heat must be removed at the same rate it is produced or the reactor core will begin to heat up. The removal of this heat is the function of the various reactor core cooling systems that provide water flow through the reactor core and then reject the heat elsewhere. However, at the Fukushima site the integrity of these systems were compromised by the large tsunami that resulted from the earthquake, and made it difficult for the operators to keep up with removing the decay heat.

The amount of the decay heat expected at various times after shutdown is well known. Below is a figure and a table that show an estimate of the decay heat of Fukushima Units 1-3 in MW as time has progressed since the earthquake. This data is not produced from measured data on the actual reactors at Fukushima, but from using a well established model that is routinely used to estimate decay heat from shutdown reactors.

Approximate reactor decay heat vs. time. The curves begin after the SCRAM of the reactors (complete and rapid control rod insertion) that occurred immediately after the earthquake.



Tabulation of approximate decay heat for the Fukushima reactors from 1 second after the scram caused by the earthquake until 1 year after the event.

Date/Time (Fukushima Time)	Fukushima Daiichi-1 Decay Heat (MW)	Fukushima Daiichi-2 & 3 Decay Heat (MW)	Percent of Full Reactor Power
3/11/11 2:46 PM	92.0	156.8	6.60%
3/11/11 2:47 PM	44.7	76.2	3.21%
3/11/11 2:48 PM	36.9	62.8	2.64%
3/11/11 2:50 PM	31.4	53.5	2.25%
3/11/11 3:00 PM	24.1	41.0	1.73%
3/11/11 3:30 PM	19.1	32.5	1.37%
3/11/11 8:00 PM	12.8	21.9	0.92%
3/12/11 8:00 AM	10.1	17.3	0.73%
3/12/11 8:00 PM	9.1	15.5	0.65%
3/13/11	8.5	14.5	0.61%
3/14/11	7.8	13.2	0.56%
3/16/11	6.9	11.8	0.50%
3/20/11	6.1	10.5	0.44%
4/1/11	5.2	8.8	0.37%
7/1/11	3.7	6.3	0.26%
10/1/11	3.3	5.6	0.23%
3/11/12	2.9	5.0	0.21%

Fukushima unit 1 has an electrical rating of 460 MWe and units 2 and 3 have an electrical rating of 784 MWe. However, due to various thermodynamic and practical constraints, the efficiency of the plants is only about

33%. Therefore, they have thermal ratings (MWth) about 3 times that of the electrical ratings and this thermal energy is the energy that must be removed, and is what is shown in the figure and table above. The decay heat drops off very slowly after about 1 day where the decay power is already below 2% of the operating power of the reactor. After a year the decay power is about 0.2% of the operating power of the reactor.

If the decay heat is not removed then the reactor fuel begins to heat up and undesirable consequences begin as the temperature rises such as rapid oxidation of the zircaloy cladding (~1200C), melting of the cladding (~1850C), and then the fuel (~2400-2860C).

Posted in decay heat | Comments Off

What are Spent Fuel Pools?

Posted on March 16, 2011 4:20 am UTC by mitnse

Spent nuclear fuel pools

Spent nuclear fuel (SNF) refers to fuel after it has fuelled a reactor. This fuel looks like new fuel in the sense that it is made of solid pellets contained in fuel rods. The only difference is that SNF contains fission products and actinides, such as plutonium, which are radioactive, meaning it needs to be shielded. Just as with the fuel rods in a shutdown reactor, the SNF produces decay heat because most of the decay radioactivity from the fission products and actinides is deposited in the fuel and converted into thermal energy (aka heat). As a result, the SNF also needs to be cooled, but at a much lower level than fuel in a recently (<12 hours) shutdown reactor as it produces only a fraction of the heat. In summary, the SNF is stored for a certain time to: 1) allow the fuel to cool as its decay heat decreases; and 2) shield the emitted radiation.

To accomplish these goals, SNF is stored in water pools and large casks that use air to cool the fuel rods. The pools are often located near the reactor (in the upper floors of the containment structure for a BWR Mark-1 containment). These pools are very large, often 40 feet deep (or larger depending on the design). The pools are made of thick concrete, lined with stainless steel. SNF assemblies are placed in racks at the bottom of these pools, so almost 30 feet of water covers the top of the SNF assemblies. The assemblies are often separated by plates containing boron which ensure a neutron chain reaction cannot start. The likelihood of such an event is further reduced because the useful uranium in the fuel has been depleted when it was in the reactor, so it is no longer capable of sustaining a chain reaction. The water in the pool is sufficient to cool the SNF, and the heat is rejected through a heat exchanger in the pool so the pool should stay at fairly constant average temperature. The water depth also ensures the radiation emitted from the SNF is shielded to a level where people can safely work around the pools.

If there is a leak in the pool or the heat exchanger fails, the pool temperature will increase. If this happens for long enough, the water may start to boil. If the boiling persists, the water level in the pool may fall below the top of the SNF, exposing the rods. This can be a problem as the air is not capable of removing enough heat from the SNF so the rods will begin to heat up. If the rods get hot enough, the zirconium-based cladding will oxidize with the steam and air, releasing hydrogen which can then ignite. These events would likely cause the clad to fail, releasing radioactive fission products like iodine, cesium, and strontium. It is important to note that each of these occurrences (cooling system failure, pool water boiling, fuel rod overheating in air, zirconium oxidation reaction) would each have to last sufficiently long in order to cause an accident, making the total likelihood of a serious situation very low.

The most significant danger if such an event were to occur is that there is no robust containment structure (like the one housing the reactor,) surrounding the SNF pool. While SNF pools themselves are very robust structures, the roof above each pool is not as strong and may have been damaged, meaning the surface of the pool may be open to the environment. As long as the water covers the fuel, this does not pose a direct threat to the environment, however it does allow for a possible dispersion of these fission products if a fire were to occur. But if the water level stays above the fuel, the threat of a large dispersion event is low.

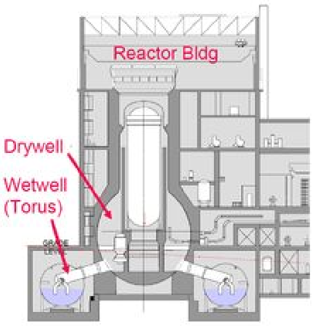
Posted in spent fuel pools | Comments Off

Unit 2 Explosion and Unit 4 Spent Fuel Pool Fire

Posted on March 15, 2011 11:57 pm UTC by mitnse

Explosion at Unit 2

It was reported earlier today that the explosion at Unit 2 of the Fukushima Daiichi plant damaged the suppression chamber. As discussed in the previous post, the suppression chamber/torus (i.e. donut shape vessel containing water) is used to depressurize the reactor. The suppression pool is designed to condense the hot steam from the reactor, but can only do so as long as sufficient cold water remains in it. It should also be noted that the suppression pool is part of the primary containment.



Hydrogen gas from the cladding oxidation with steam collected in the suppression pool and ignited. This scenario differs from those of units 1 and 3 where the explosion occurred outside the primary containment in the upper part of the reactor building. The reasons why the steam/gas mixture was not released to the reactor building are still not clear. This breach of primary containment is certainly more serious than the situation in units 1 and 3. Seawater is still being pumped in the containment and the reactor vessel. At this time radioactive releases from unit 2 have been similar to the ones seen from units 1 and 3.

Fire at Unit 4 spent fuel pool

Recent reports by TEPCO indicate that an oil leak in a cooling water pump was the cause for the fire that burned for approximately 2 hours on Tuesday. On Wednesday morning (local time), another fire broke out, but it is reported the fire is not at the spent fuel pool. The cause is still unknown.

Reactor spent fuel pools

Spent fuel pools are used to cool down used nuclear fuel after it is removed from the reactor. The used nuclear fuel still contains residual heat from the radioactive decay of the fission product and must be stored in a cooled pool of water until intermediate or ultimate disposal. If insufficient cooling is provided to the pools, the water boils potentially exposing the spent fuel. As the temperature increases, the cladding would oxidize with the steam releasing hydrogen which can then ignite. This would also create fuel failures, releasing radioactive gases such as iodine, cesium and strontium.

It should be noted that unit 4 was under a 105-day long outage and that the fuel in the reactor had been moved to the spent fuel pool. Reports throughout the day indicated that the temperature of the spent fuel pool was increasing.

Current reports also indicate that the temperatures in the spent fuel pools of units 5 and 6 are also increasing.

http://nei.cachefly.net/newsandevents/information-on-the-japanese-earthquake-and-reactors-in-that-region/

Posted in Uncategorized | Comments Off

Explanation of Hydrogen Explosions at Units 1 and 3

Posted on March 15, 2011 4:51 pm UTC by mitnse

Explosions at units 1 and 3 occurred due to similar causes. When an incident occurs in a nuclear power plant such as a loss of coolant accident or when power is lost, usually the first response is to depressurize the reactor. This is done by opening pressure relief valves on the reactor vessel. The water/steam mixture will then flow down into the suppression pool, which for this design of a reactor is in the shape of a torus (technical term for the shape of a donut). By blowing the hot steam into the suppression pool some of the steam is condensed to liquid phase, which helps keep the pressure low in the containment.

The pressure in the reactor vessel is reduced by venting the water/steam mixture. It is much easier to pump water into the vessel when it is at a reduced pressure, thus making it easier to keep the fuel cooled. This procedure was well underway after the earthquake. Unfortunately, because of the enormous magnitude of the earthquake, an equally large tsunami was created. This tsunami disabled the onsite diesel generators as well as the electrical switchyard. Without power to run pumps and remove heat, the temperature of the water in the reactor vessel began to rise.

With the water temperature rising in the core, some of the water began to vaporize and eventually uncovered some of the fuel rods. The fuel rods have a layer of cladding material made of a zirconium alloy. If zirconium is hot enough and is in the presence of oxygen (The steam provides the oxygen) then it can undergo a reaction that produces hydrogen gas. Hydrogen at concentrations above 4% is highly flammable when mixed with oxygen; however, not when it is also in the presence of excessive steam.

As time went on, the pressure in the containment rose to a much higher level than usual. The containment represents the largest barrier to the release of radioactive elements to the environment and should not be allowed to fail at any cost. The planned response to an event like this is to vent some of the steam to the atmosphere, just to keep the pressure under control.

Exactly what happened next is not verified; however, the following is very likely the general explanation for the explosion. It was decided to vent the steam through some piping that led to a space above and outside containment, but inside the reactor building. At this point, the steam and hydrogen gas were mixed with the air in the top of the reactor building. This was still not an explosive mixture because large amounts of steam were mixed with the hydrogen and oxygen (from the air). However, the top of this building is significantly colder than inside the containment due to the weather outside. This situation would lead to some of the steam condensing to water, thereby concentrating the hydrogen and air mixture. This likely went on for an extended period of time, and at some point an ignition source (such as a spark from powered equipment) set off the explosion that was seen in units 1 and 3. The top of the reactor building was severely damaged; however, the containment structure showed no signs of damage.

Right after the explosions there were spikes in the radiation levels detected, because there were some radioactive materials in the steam. When the zirconium alloy cladding reacted to make hydrogen, it released some fission products. The vast majority of the radioactive materials in the fuel will remain in the fuel. However, some of the fission products are noble gases (xenon, Xe and krypton, Kr) and will immediately leave the fuel rods when the cladding integrity is compromised. Fortunately, Xe and Kr are not a serious radiological hazard because they are chemically inert and will not react with humans or plants. Additionally, small quantities of iodine (I) and cesium (Cs) can be entrained with the steam. When the steam was vented to the reactor building, the Xe and Kr would have followed as well as some small amounts of I and Cs. Thus, when the roof of the reactor building was damaged , these radionuclides that were in the reactor building would have also been released. This is the reason a sudden spike was seen in radiation levels. These heightened radiation levels quickly decreased. This is because there was no damage to the containment which would increase the quantities of radionuclide released, and because the radionuclides released during the explosion quickly decayed away or dispersed.

Unit 2 explosion

Recent information indicates that unit 2 may have suffered a containment breach. Pressure relief of unit 2 was complicated by a faulty pressure relief valve, which complicated the injection of sea water and the evacuation of the steam and hydrogen. It is reported that the fuel rods were completely exposed twice. More details to follow.

Unit 4 fire

A fire was reported at unit 4 which was in a shutdown state during the earthquake and tsunami for a planned outage. Latest reports indicate that the fire was put out. More details to come.

Posted in Uncategorized | Comments Off

Damage to Fukushima Daiichi 2 [World Nuclear News]

Posted on March 15, 2011 2:27 am UTC by mitnse

Loud noises were heard at Fukushima Daiichi 2 at 6.10am this morning. A major component beneath the reactor may be damaged.

Confirmation of loud sounds this morning came from the Nuclear and Industrial Safety Agency (NISA). It noted that “the suppression chamber may be damaged.” It is not clear that the sounds were explosions.

Also known as the torus, this large doughnut-shaped structure sits in the centre of the reactor building at a lower level than the reactor. It contains a very large body of water to which steam can be directed in emergency situations. The steam then condenses and reduces pressure in the reactor system.

The pressure in the pool was seen to decrease from three atmospheres to one atmosphere after the noise, suggesting possible damage. Radiation levels on the edge of the plant compound briefly spiked at 8217 microsieverts per hour but later fell to about a third that.

A close watch is being kept on the radiation levels to ascertain the status of containment. As a precaution Tokyo Electric Power Company has evacuated all non-essential personnel from the unit. The company’s engineers continue to pump seawater into the reactor pressure vessel, in an effort to cool it.

Prime minister Naoto Kan has requested that everyone withdraw from the ten kilometer evacuation zone around the nuclear power plant and that people that stay within remain indoors. He said his advice related to the overall picture of safety developments at Fukushima Daiichi, rather than those at any individual reactor unit.

http://www.world-nuclear-news.org/RS_Possible_damage_at_Fukushima_Daiichi_2_1503111.html

Posted in Uncategorized | Comments Off

Status Update – 3/14/11 at 1:00 pm EST (Source – The Federation of Electric Power Companies of Japan (FEPC))

Posted on March 15, 2011 1:40 am UTC by mitnse

As of 1:00PM (EST), March 14, 2011

* Radiation Levels
o At 9:37AM (JST) on March 14, a radiation level of 3130 micro sievert was recorded at the Fukushima Daiichi Nuclear Power Station.
o At 10:35AM on March 14, a radiation level of 326 micro sievert was recorded at the Fukushima Daiichi Nuclear Power Station.
o Most recently, at 2:30PM on March 14, a radiation level of 231 micro sievert was recorded at Fukushima Daiichi Nuclear Power Station.
* Fukushima Daiichi Unit 1 reactor
o As of 12:00AM on March 15, the injection of seawater continues into the primary containment vessel.
* Fukushima Daiichi Unit 2 reactor
o At 12:00PM on March 14, in response to lower water levels, TEPCO began preparations for injecting seawater into the reactor core.
o At 5:16PM on March 14, the water level in the reactor core covered the top of the fuel rods.
o At 6:20PM on March 14, TEPCO began to inject seawater into the reactor core.
o For a short time around 6:22PM on March 14, the water level inside the reactor core fell below the lower measuring range of the gauge. As a result, TEPCO believes that the fuel rods in the reactor core might have been fully exposed.
o At 7:54PM on March 14, engineers confirmed that the gauge recorded the injection of seawater into the reactor core.
o At 8:37PM on March 14, in order to alleviate the buildup of pressure, slightly radioactive vapor, that posed no health threat, was passed through a filtration system and emitted outside via a ventilation stack from Fukushima Daiichi Unit 2 reactor vessel.
* Fukushima Daiichi Unit 3 reactor
o At 11:01AM on March 14, an explosion occurred at Fukushima Daiichi Unit 3 reactor damaging the roof of the secondary containment building. Caused by the interaction of hydrogen and oxygen vapor, in a fashion to Unit 1 reactor, the explosion *did not damage the primary containment vessel* or the reactor core.
o As of 12:38AM (JST) on March 15, the injection of seawater has been suspended.

* Fukushima Daini Unit 1 reactor
o As of 1:24AM on March 14, TEPCO commenced the cooling process after the pumping system was restored.
o At 10:15AM on March 14, TEPCO confirmed that the average water temperature held constant below 212 degrees Fahrenheit.
* Fukushima Daini Unit 2 reactor
o At 7:13AM on March 14, TEPCO commenced the cooling process.
o As of 3:52PM on March 14, the cooling function was restored and the core temperature was stabilized below 212 degrees Fahrenheit.
* Fukushima Daini Unit 3 reactor
o As of 12:15PM on March 13, reactor has been cooled down and stabilized.
* Fukushima Daini Unit 4 reactor__
o At 3:42PM on March 14, cooling of the reactor commenced, with TEPCO engineers working to achieve cold shutdown.

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Modified version of original post written by Josef Oehmen

Posted on March 13, 2011 5:43 pm UTC by mitnse

The original post of Josef Oehmen appeared on Morgsatlarge. Due to the large and unexpected popularity of the original post, Dr.Oehmen handed the blog to the MIT Nuclear Science And Engineering Department in an effort to correct the presented information and provide a starting point. It has since been migrated to this location and edited considerably by members of the NSE Community. It should be noted that Josef Oehmen is not affiliated to the MIT NSE department.
***** Please note that the original post in no way reflects the views of the authors of the site. The authors have been monitoring the situation, and are presenting facts on the situation as they develop. The original article was adopted as the authors believed it provided a good starting point to provide a summary background on the events at the Fukushima plant. The authors do not intend to speculate about the safety of the public and the environment, and would like to express their sympathies and condolences to the people of Japan following the recent natural disaster.*****
The original post written by Dr Josef Oehmen "Why I am not worried about Japan's nuclear reactors." are being reposted in different languages. They have not been checked / verified.

•Japanese
•German
•Spanish

We will have to cover some fundamentals, before we get into what is going on.

Construction of the Fukushima nuclear power plants

The plants at Fukushima are Boiling Water Reactors (BWR for short). A BWR produces electricity by boiling water, and spinning a a turbine with that steam. The nuclear fuel heats water, the water boils and creates steam, the steam then drives turbines that create the electricity, and the steam is then cooled and condensed back to water, and the water returns to be heated by the nuclear fuel. The reactor operates at about 285 °C.

The nuclear fuel is uranium oxide. Uranium oxide is a ceramic with a very high melting point of about 2800 °C.

The fuel is manufactured in pellets (cylinders that are about 1 cm tall and 1 cm in diameter). These pellets are then put into a long tube made of Zircaloy (an alloy of zirconium) with a failure temperature of 1200 °C (caused by the auto-catalytic oxidation of water), and sealed tight. This tube is called a fuel rod. These fuel rods are then put together to form assemblies, of which several hundred make up the reactor core.

The solid fuel pellet (a ceramic oxide matrix) is the first barrier that retains many of the radioactive fission products produced by the fission process. The Zircaloy casing is the second barrier to release that separates the radioactive fuel from the rest of the reactor.

The core is then placed in the pressure vessel. The pressure vessel is a thick steel vessel that operates at a pressure of about 7 MPa (~1000 psi), and is designed to withstand the high pressures that may occur during an accident. The pressure vessel is the third barrier to radioactive material release.

The entire primary loop of the nuclear reactor – the pressure vessel, pipes, and pumps that contain the coolant (water) – are housed in the containment structure. This structure is the fourth barrier to radioactive material release. The containment structure is a hermetically (air tight) sealed, very thick structure made of steel and concrete. This structure is designed, built and tested for one single purpose: To contain, indefinitely, a complete core meltdown. To aid in this purpose, a large, thick concrete structure is poured around the containment structure and is referred to as the secondary containment.

Both the main containment structure and the secondary containment structure are housed in the reactor building. The reactor building is an outer shell that is supposed to keep the weather out, but nothing in. (this is the part that was damaged in the explosions, but more to that later).

Fundamentals of nuclear reactions

The uranium fuel generates heat by neutron-induced nuclear fission. Uranium atoms are split into lighter atoms (aka fission products). This process generates heat and more neutrons (one of the particles that forms an atom). When one of these neutrons hits another uranium atom, that atom can split, generating more neutrons and so on. That is called the nuclear chain reaction. During normal, full-power operation, the neutron population in a core is stable (remains the same) and the reactor is in a critical state.

It is worth mentioning at this point that the nuclear fuel in a reactor can never cause a nuclear explosion like a nuclear bomb. At Chernobyl, the explosion was caused by excessive pressure buildup, hydrogen explosion and rupture of all structures, propelling molten core material into the environment. Note that Chernobyl did not have a containment structure as a barrier to the environment. Why that did not and will not happen in Japan, is discussed further below.

In order to control the nuclear chain reaction, the reactor operators use control rods. The control rods are made of boron which absorbs neutrons. During normal operation in a BWR, the control rods are used to maintain the chain reaction at a critical state. The control rods are also used to shut the reactor down from 100% power to about 7% power (residual or decay heat).

The residual heat is caused from the radioactive decay of fission products. Radioactive decay is the process by which the fission products stabilize themselves by emitting energy in the form of small particles (alpha, beta, gamma, neutron, etc.). There is a multitude of fission products that are produced in a reactor, including cesium and iodine. This residual heat decreases over time after the reactor is shutdown, and must be removed by cooling systems to prevent the fuel rod from overheating and failing as a barrier to radioactive release. Maintaining enough cooling to remove the decay heat in the reactor is the main challenge in the affected reactors in Japan right now.

It is important to note that many of these fission products decay (produce heat) extremely quickly, and become harmless by the time you spell "R-A-D-I-O-N-U-C-L-I-D-E." Others decay more slowly, like some cesium, iodine, strontium, and argon.

What happened at Fukushima (as of March 12, 2011)

The following is a summary of the main facts. The earthquake that hit Japan was several times more powerful than the worst earthquake the nuclear power plant was built for (the Richter scale works logarithmically; for example the difference between an 8.2 and the 8.9 that happened is 5 times, not 0.7).

When the earthquake hit, the nuclear reactors all automatically shutdown. Within seconds after the earthquake started, the control rods had been inserted into the core and the nuclear chain reaction stopped. At this point, the cooling system has to carry away the residual heat, about 7% of the full power heat load under normal operating conditions.

The earthquake destroyed the external power supply of the nuclear reactor. This is a challenging accident for a nuclear power plant, and is referred to as a "loss of offsite power." The reactor and its backup systems are designed to handle this type of accident by including backup power systems to keep the coolant pumps working. Furthermore, since the power plant had been shut down, it cannot produce any electricity by itself.

For the first hour, the first set of multiple emergency diesel power generators started and provided the electricity that was needed. However, when the tsunami arrived (a very rare and larger than anticipated tsunami) it flooded the diesel generators, causing them to fail.

One of the fundamental tenets of nuclear power plant design is "Defense in Depth." This approach leads engineers to design a plant that can withstand severe catastrophes, even when several systems fail. A large tsunami that disables all the diesel generators at once is such a scenario, but the tsunami of March 11th was beyond all expectations. To mitigate such an event, engineers designed an extra line of defense by putting everything into the containment structure (see above), that is designed to contain everything inside the structure.

When the diesel generators failed after the tsunami, the reactor operators switched to emergency battery power. The batteries were designed as one of the backup systems to provide power for cooling the core for 8 hours. And they did.

After 8 hours, the batteries ran out, and the residual heat could not be carried away any more. At this point the plant operators begin to follow emergency procedures that are in place for a "loss of cooling event." These are procedural steps following the "Depth in Defense" approach. All of this, however shocking it seems to us, is part of the day-to-day training you go through as an operator.

At this time people started talking about the possibility of core meltdown, because if cooling cannot be restored, the core will eventually melt (after several days), and will likely be contained in the containment. Note that the term "meltdown" has a vague definition. "Fuel failure" is a better term to describe the failure of the fuel rod barrier (Zircaloy). This will occur before the fuel melts, and results from mechanical, chemical, or thermal failures (too much pressure, too much oxidation, or too hot).

However, melting was a long ways from happening and at this time, the primary goal was to manage the core while it was heating up, while ensuring that the fuel cladding remain intact and operational for as long as possible.

Because cooling the core is a priority, the reactor has a number of independent and diverse cooling systems (the reactor water cleanup system, the decay heat removal, the reactor core isolating cooling, the standby liquid cooling system, and others that make up the emergency core cooling system). Which one(s) failed when or did not fail is not clear at this point in time.

Since the operators lost most of their cooling capabilities due to the loss of power, they had to use whatever cooling system capacity they had to get rid of as much heat as possible. But as long as the heat production exceeds the heat removal capacity, the pressure starts increasing as more water boils into steam. The priority now is to maintain the integrity of the fuel rods by keeping the temperature below 1200°C, as well as keeping the pressure at a manageable level. In order to maintain the pressure of the system at a manageable level, steam (and other gases present in the reactor) have to be released from time to time. This process is important during an accident so the pressure does not exceed what the components can handle, so the reactor pressure vessel and the containment structure are designed with several pressure relief valves. So to protect the integrity of the vessel and containment, the operators started venting steam from time to time to control the pressure.

As mentioned previously, steam and other gases are vented. Some of these gases are radioactive fission products, but they exist in small quantities. Therefore, when the operators started venting the system, some radioactive gases were released to the environment in a controlled manner (ie in small quantities through filters and scrubbers). While some of these gases are radioactive, they did not pose a significant risk to public safety to even the workers on site. This procedure is justified as its consequences are very low, especially when compared to the potential consequences of not venting and risking the containment structures' integrity.

During this time, mobile generators were transported to the site and some power was restored. However, more water was boiling off and being vented than was being added to the reactor, thus decreasing the cooling ability of the remaining cooling systems. At some stage during this venting process, the water level may have dropped below the top of the fuel rods. Regardless, the temperature of some of the fuel rod cladding exceeded 1200 °C, initiating a reaction between the Zircaloy and water. This oxidizing reaction produces hydrogen gas, which mixes with the gas-steam mixture being vented. This is a known and anticipated process, but the amount of hydrogen gas produced was unknown because the operators didn't know the exact temperature of the fuel rods or the water level. Since hydrogen gas is extremely combustible, when enough hydrogen gas is mixed with air, it reacts with oxygen. If there is enough hydrogen gas, it will react rapidly, producing an explosion. At some point during the venting process enough hydrogen gas built up inside the containment (there is no air in the containment), so when it was vented to the air an explosion occurred. The explosion took place outside of the containment, but inside and around the reactor building (which has no safety function). Note that a subsequent and similar explosion occurred at the Unit 3 reactor. This explosion destroyed the top and some of the sides of the reactor building, but did not damage the containment structure or the pressure vessel. While this was not an anticipated event, it happened outside the containment and did not pose a risk to the plant's safety structures.

Since some of the fuel rod cladding exceeded 1200 °C, some fuel damage occurred. The nuclear material itself was still intact, but the surrounding Zircaloy shell had started failing. At this time, some of the radioactive fission products (cesium, iodine, etc.) started to mix with the water and steam. It was reported that a small amount of cesium and iodine was measured in the steam that was released into the atmosphere.

Since the reactor's cooling capability was limited, and the water inventory in the reactor was decreasing, engineers decided to inject sea water (mixed with boric acid – a neutron absorber) to ensure the rods remain covered with water. Although the reactor had been shut down, boric acid is added as a conservative measure to ensure the reactor stays shut down. Boric acid is also capable of trapping some of the remaining iodine in the water so that it cannot escape, however this trapping is not the primary function of the boric acid.

The water used in the cooling system is purified, demineralized water. The reason to use pure water is to limit the corrosion potential of the coolant water during normal operation. Injecting seawater will require more cleanup after the event, but provided cooling at the time.

This process decreased the temperature of the fuel rods to a non-damaging level. Because the reactor had been shut down a long time ago, the decay heat had decreased to a significantly lower level, so the pressure in the plant stabilized, and venting was no longer required.

UPDATE – 3/14 8:15 pm EST

Units 1 and 3 are currently in a stable condition according to TEPCO press releases, but the extent of the fuel damage is unknown. That said, radiation levels at the Fukushima plant have fallen to 231 micro sieverts (23.1 millirem) as of 2:30 pm March 14th (local time).

UPDATE – 3/14 10:55 pm EST

The details about what happened at the Unit 2 reactor are still being determined. The post on what is happening at the Unit 2 reactor contains more up-to-date information. Radiation levels have increased, but to what level remains unknown.

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