Entergy Nuclear Issue Brief
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Hardened Structures

How are nuclear plants designed to withstand natural disasters?

- The U.S. Nuclear Regulatory Commission requires all safety-significant structures, systems and components be designed to withstand the most severe natural phenomena historically reported for each plant's surrounding area, plus a significant margin for error. The NRC includes an added safety margin to ensure that the standards account for the risk that a future earthquake or flood could be more severe than any recorded historical event.

- Nuclear plant designs include consideration of seismic events and other likely natural disasters such as hurricanes, tornados and flooding. It is important not to extrapolate earthquake and tsunami data from one location of the world to another when evaluating these natural hazards. These catastrophic natural events are very region- and location-specific, based on tectonic and geological fault line locations and proximity to oceans.

- As a result of extremely rigorous reviews and enhancements since 9/11, America's nuclear energy industry is even better protected and well prepared to prevent, respond and mitigate extreme scenarios beyond regulatory requirements.

- All dry fuel storage facilities meet federal regulatory design requirements including that casks are designed to withstand the effects of natural phenomena such as tornadoes, lightning, hurricanes, floods, tsunami and seiches. All operating Entergy interim spent fuel storage facilities have been evaluated against the worst case postulated flood; canisters remain sealed during flood conditions.

Seismic Capabilities for Nuclear Plants
Every U.S. nuclear power plant is designed to withstand earthquakes of a magnitude equivalent to or greater than the largest postulated earthquake for the region. The U.S. Geological Survey conducts continuous research of earthquake history and geology, and publishes updated seismic hazard curves for various regions in the continental U.S. These curves are updated approximately every six years.

Nuclear plants are built to withstand an earthquake that produces the maximum vibratory ground motion, with structures, systems and components designed to maintain safety, including:
- Integrity of the reactor vessel that houses the reactor and cooling water
- Capability to shut down the reactor and maintain it in a safe shutdown condition
- Capability to prevent or mitigate the consequences of accidents that could result in potential offsite radiation exposures

Critical buildings and systems for nuclear plants include earthquake-resistant design and construction features that exceed commercial or industrial requirements.

Plant designers evaluate the supporting soil and rock to ensure they can adequately support the buildings. Engineers depend on precise measurements of ground motion rather than other measures like the Richter magnitude scale, which assigns a single number indicative of an earthquake's total seismic energy.

Designers also compare the design against the stress limits of the materials used in plant construction. Plant mechanical and electrical systems that have safety functions likewise are designed with substantial safety margins to withstand earthquakes. The evaluation of systems and equipment uses state-of-the-art analytical methods, as well as earthquake simulation testing, to demonstrate that the systems and equipment will function properly during and after an earthquake.

Nuclear plant seismic design is performed in accordance with NRC regulations and national codes and standards. Compliance with these standards and regulations ensures a substantial safety margin with respect to earthquakes for the life of the plant. The codes and standards come from a variety of organizations, including:

- American Nuclear Society
- American Society of Civil Engineers
- American Society of Mechanical Engineers
- Institute of Electrical and Electronics Engineers
- American Concrete Institute
- American Institute of Steel Construction

Every U.S. nuclear power plant performs regular, in-depth seismic analyses, and the NRC regularly reviews new information on earthquake sources and ground motion models. Regulations are modified accordingly.

Each nuclear plant has seismic instrumentation to record earthquake-induced motions at the site. The recordings are used to evaluate the level of earthquake vibrations at the plant and determine if the plant is required to shut down, based on pre-established criteria. Plant operators will shut down the reactor even if the seismic event is well within levels the design can accommodate. Operators then perform extensive inspections prior to restarting the plant.

Tsunami Protection

The U.S. Nuclear Regulatory Commission's requirements include consideration of tsunamis up to 200 miles from the site location. These considerations involve historical data, various wave propagation models, wave buildup, inundation and drawdown, generation of hydraulic forces, effects of sedimentation, deposition and erosion disasters such as hurricanes, tornados and flooding.

Design basis for tsunamis and similar catastrophic natural events are site- and location-specific, based on proximity to oceans and geological distinctions. Data for one plant is not necessarily applicable to all other nuclear sites worldwide.

Flood Protection

Plants are hardened against potential flooding. Emergency core cooling systems are watertight; they are sealed, with submarine doors for access. Fuel tanks for emergency diesels are buried underground or secured to ensure they cannot float away. Fuel tanks for the additional backup "blackout" diesel generators are either underground or enclosed in a building. Electrical switchgear for emergency operations at the plants is protected from flooding, for example, by elevating it above potential flood levels.

Spent Fuel Pools
The used fuel pools at the Fukushima Daiichi reactors are located at the top of the reactor buildings for ease of handling during refueling operations.

In the United States, used fuel pools are robust concrete and steel structures designed to protect the fuel from even the most severe events. Although some of them are located on the upper floor of the reactor building, the structure surrounding the pools constitutes part of the secondary containment. Pools are designed with systems to maintain the temperature and water levels sufficient to provide cooling and radiation shielding.

The water level in a used fuel pool typically is 16 feet or more above the top of the fuel assemblies. The rate at which the pool water level would decrease (due to evaporation or mild boiling) in the absence of cooling system function would not be expected to lower water levels by more than a few percent per day.

Used fuel pools are designed so that the water in the pool cannot drain down as a result of damage to the piping or cooling systems. The pools do not have drains in the sides or the floor of the pool structure. The only way to rapidly drain down the pool is in the case of structural damage to the walls or the floor.

The systems that cool and maintain water levels in the pools are designed to withstand severe events. If these systems are unable to function, the heat generated by the used fuel would result in a slow increase in the temperature of the spent fuel pool water. The operating temperature of the pools is typically around 40 degrees C or 100 degrees F (the boiling point for water is 100 C or 212 F).

This slow increase in temperature would result in an increased evaporation rate. Rapid evaporation of the water will not occur. Exact evaporation rates would depend on the amount of used fuel in the pool and how long it has cooled.

Even if the water level in the pools were to decrease sufficiently so that the fuel was exposed to air, the same level of overheating that can occur as a result of exposed fuel in a reactor would not occur in the used fuel pool because the used fuel assemblies in the pool are cooler than in the reactor.

If the water level decreases below the top of the fuel assembly, oxidation of the zirconium cladding could occur. This oxidation could result in some hydrogen generation. However, only the fuel assemblies with the least cooling time (on the order of weeks after discharge from the reactor) would be susceptible to this oxidation. The rate of hydrogen generation depends on the temperature of the fuel assembly, with hotter temperatures leading to higher gas generation rates. However, the temperature of the cladding must rise to approximately 1000 C before significant hydrogen generation rate occurs. This is extremely unlikely to occur after as little as 120 days (16 weeks) of cooling. As a reference, the melting point of zirconium is approximately 1800 degrees C.

There has been some speculation that if the used fuel pool were completely drained, the zirconium cladding might ignite and a “zirconium fire” might occur. Studies performed by the Department of Energy indicate that it is virtually impossible to ignite zirconium tubing.

Dry Cask Storage
All dry fuel storage facilities meet federal regulatory design requirements, including cask designs to withstand the effects of natural phenomena such as tornadoes, lightning, hurricanes, floods, tsunamis and seiches. All operating Entergy independent spent fuel storage installation sites have been evaluated against the worst case postulated flood, and the canisters will remain sealed during flood conditions.

Waterford and Pilgrim do not have operating dry fuel storage facilities as of March 2011. Waterford dry fuel storage construction is complete to support future operation.

Fire Protection
Nuclear power plants have comprehensive fire protection systems, equipment and procedures to ensure safety, as well as programs to manage combustible materials and ignition sources. No fires have significantly challenged nuclear power systems in more than 30 years.

All nuclear plants are subject to stringent fire protection requirements established by the U.S. Nuclear Regulatory Commission to protect critical systems needed to maintain the reactor and to shut it down safely in the event of a fire large enough to threaten those systems. The NRC mandates that plants comply with requirements issued in 1981 or with a voluntary performance-based rule issued in 2004. The voluntary rule is based on a consensus fire protection standard published by the National Fire Protection Association.

Fire protection at nuclear plants includes providing sufficient fire safeguards for structures, systems and components important to safety so that, in the event a fire is not extinguished promptly, it will not prevent essential plant safety functions from being performed.

Through the early 1970s, nuclear power plants generally followed the same local fire protection codes that governed other industrial facilities. However, a review of a 1975 fire at a nuclear power plant led to sweeping changes in the way fire protection is managed at nuclear power plants. The NRC issued fire protection guidance to utilities shortly after the fire and again in 1981. These detailed requirements (10 CFR 50.48 and 10 CFR 50, Appendix R) address fire prevention and detection, fire brigade training and other areas of fire protection.

The NRC's original regulations require plants to protect critical safety structures and reactor equipment "important to safe shutdown" in the unlikely event of a fire. Utilities use various systems and features, including fire protection barriers, physical separation and fire detection and suppression equipment to meet these requirements. A risk-informed approach to fire protection assesses plant design and actual fire risks in each plant area, taking into account such factors as the amount of combustible material, potential ignition sources and fire suppression systems.

Following 9/11, as part of our steps taken to enhance capabilities to respond to potential terrorist attack, including mitigation of spent fuel pool fire risk, Entergy implemented all necessary recommendations at each unit where industry actions dictated enhancements. Included in our actions were assurance of the ability to spray water over spent fuel pools and placement of used fuel in the pool to equalize temperatures from older, cooler fuel with the more recent, warmer used fuel. Both of these actions are consistent with recommendations made in 2006 by a National Academy of Sciences committee. Our actions were among other enhanced plant-specific mitigation capabilities important to preventing fuel damage caused by a large explosion or fire.

In 2004, the NRC issued 10 CFR 50.48(c), a voluntary approach — also known as NFPA 805 — allowing risk-informed approaches that model expected fire sizes and effects. The NRC has endorsed guidance developed by the Nuclear Energy Institute to aid plants in implementing the standard.

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