



Entergy Nuclear Issue Brief

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Design-Related Safety

How does plant design assure its safety during a catastrophic event?

- It will take some time to clearly understand what has happened to the Japanese nuclear power plants, and it would be premature to speculate to what degree unique design or operator response may have contributed to the challenges caused by the tsunami taking out their backup power source.
- Nuclear plants in the United States are designed and built to withstand threats specific to their location, including earthquakes, floods and other natural disasters. Federal regulators will grant a license only if the plant is built above and beyond any credible natural or manmade threat.
- The nuclear power industry will learn from this event and will modify our facility designs as needed to make them safer in the future.

Basic Explanation of Failure to Provide Water Cooling to a Nuclear Reactor

In a nuclear emergency, the most important action is to ensure the nuclear fuel in the reactor core and the spent fuel pool is covered with water to provide cooling, removing any heat from the fuel rods. Without adequate cooling, the fuel rods will be damaged. Should the final containment structure fail, radiation from these melting fuel rods would be released to the atmosphere, and additional protective measures could be necessary, depending on factors such as prevailing wind patterns.

If plant operators cannot move water through the reactor core, the water in the reactor vessel begins to boil and turn to steam, increasing pressure inside the reactor vessel. In order to keep the reactor vessel pressure below design limits, this steam is then piped into what is called a suppression pool of water. Some plants use a type of pool called a torus, a large doughnut-shaped tank that sits beneath the reactor vessel. Because of their different design, pressurized water reactors do not require a suppression pool.

Eventually, the water in the suppression pool reaches "saturation," meaning that it cannot absorb any additional heat and it, too, begins to boil, increasing pressure in containment. In order to stay within design limits for the primary containment, operators reduce pressure by venting steam through filters (to scrub out some radioactive particles) to the atmosphere through the vent stack.

If operators cannot pump additional water into the reactor vessel, the water level will begin to drop, uncovering the fuel rods. If the fuel remains uncovered for an extended period of time, fuel damage, possibly including melting of fuel, may occur. If there is fuel damage, and steam is being vented to the suppression pool, then to primary containment, then to secondary containment (in order to

relieve pressure build-up on plant systems), small quantities of unfiltered radioactive materials will escape to the environment, but at levels not considered to be a threat to public health or safety.

Design of Entergy's Plants

Entergy owns five boiling water reactors: Vermont Yankee, Pilgrim, FitzPatrick, River Bend and Grand Gulf; Cooper, for which Entergy provides management services, is also a BWR. FitzPatrick, Pilgrim and Vermont Yankee use Mark I containment.

While the design of the reactors in Japan have various similarities and differences from our own, basic safety systems at the Fukushima Daiichi units are designed to function in the manner that our U.S. nuclear plants do, using backup power sources to add water to the reactor to keep the fuel from overheating. In Japan, all external power and emergency power was lost due to a series of catastrophic events, starting with one of the largest earthquakes in recorded history followed by the tsunami.

Mark I Containment in the United States

The Mark I containment meets all Nuclear Regulatory Commission design and safety requirements necessary to protect public health and safety. In 1975, a safety study referred to as the WASH-1400 study analyzed the Mark I containment design in great detail. The NRC analysis found that the BWR Mark I risk was dominated by two scenarios: station blackout and anticipated transients without scram. The NRC subsequently issued regulations for both of these sequences as well as other actions to reduce the probability of failure of containment, which operators implemented to increase the margin of safety.

Nuclear plant design barriers			
Every nuclear power plant in the United States is designed and built with multiple layers of safety. In a boiling water reactor, the major barriers between the fuel and the environment include the fuel cladding, the reactor coolant system pressure boundary, the containment structure and the secondary containment. <i>Source: GE</i>			
Barrier	BWR	PWR	How it protects
Barrier 1 – Fuel and Fuel Cladding	<ul style="list-style-type: none"> - Normal bulk coolant temp ~540 F - Cladding oxidation starts ~1,800 F - Cladding temperature regulatory limit 2,200 F - Self-sustaining oxidation reaction ~2,800 F - Cladding melts or ruptures ~3,375 F - Fuel melts ~5,080 F 	<ul style="list-style-type: none"> - Normal average coolant temperature ~544 to ~601 F - Cladding oxidation starts ~1,800 F - Cladding temperature regulatory limit 2,200 F - Self-sustaining oxidation reaction ~2,800 F - Cladding melts or ruptures ~3,375 F - Fuel melts ~5,080 F 	Fuel cladding surrounds the fuel and prevents escape of fission products into the reactor coolant system.
Barrier 2 – Reactor Coolant System Pressure Boundary	<ul style="list-style-type: none"> - Normal operating pressure ~1,025 PSIG - Design pressure ~1,250 PSIG - Regulatory limit ~1,325 PSIG at steam dome 	<ul style="list-style-type: none"> - Normal operating pressure ~2,250 PSIA - Design pressure ~2,500 PSIA - Regulatory limit ~2,750 PSIA 	The reactor coolant system pressure boundary keeps contained any radionuclides that could escape the fuel cladding. Includes the

			reactor vessel and connected piping.
Barrier 3 – Containment	Design pressure (measured in PSIG) - For BWR6: 15 (Grand Gulf and River Bend); Ultimate pressure is 62 and 53 psig, respectively - BWR3 and 4: 56 (JAF, Pilgrim, VY)	Design pressure (measured in PSIG) - For ANO: 58 - For Palisades: 55 - For IPEC: 47 - For W3: 44	Containment holds radionuclides that could escape from the reactor coolant system. It is a steel vessel surrounded by a concrete shield wall or a steel liner on a concrete wall.
Barrier 4 – Secondary Containment	Normally maintains a slight negative pressure to ensure that any leakage of radioisotopes from containment is diluted and filtered. Requires sealed walls, floors, penetrations, electric motor driven exhaust fans and filters to function.	Not applicable for a PWR because of system design.	In a BWR, the secondary containment limits release to the environment of radioisotopes that may leak from the primary containment and other engineered safety systems.

Multiple Barriers of Protection

Note: Various nuclear plant designs vary from this, but all include multiple barriers

