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Nuclear Reactor Crisis in Japan FAQs

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Questions about U.S. Reactor Safety

Can plants in the United States withstand disasters such as the earthquake and tsunami that crippled nuclear reactors in Japan?

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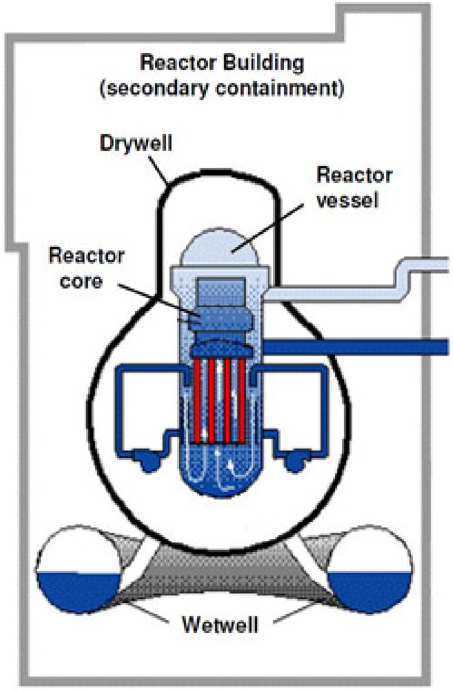
What are the different types of containment that prevent radiation from getting into the environment?

The nuclear fuel is inside a reactor vessel, made of steel. The reactor vessel, in turn, is inside the primary containment structure. The primary containment consists of two parts, the “drywell” and the “wetwell,” or “torus.”



Mark I containment system.
Figure adapted from www.nucleartourist.com

The drywell has a concrete floor and sides of steel-lined concrete, and is designed to contain any melted fuel that has escaped from the reactor vessel and the radioactivity emitted by the fuel. The wetwell, which sits below the drywell and is connected to it via pipes, contains water and is designed to reduce excess pressure in the drywell. Steam from the drywell is pushed into the wetwell, where it is cooled by the water and condensed, thereby alleviating pressure in the drywell.

The primary containment structure sits inside the secondary containment, which is the reactor building. The building is designed to be kept at a lower pressure than the outside, so that air will leak into the building rather than out.

The air in the reactor building is sent through filters to remove any radiation before being released to the outside. Under normal conditions, the primary containment has an air leakage rate equal to about one percent of its volume per day, and the building ventilation system is designed to handle this volume of air.

If the primary containment leaks, this pressure difference will minimize the amount of radioactivity that escapes to the outside of the building. However, the building ventilation system is designed to handle a daily volume of air equal to about 1 percent of the volume of the primary containment, so a leak rate greater than this will likely overwhelm the filtering system.

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What is the difference between a meltdown and a loss of containment?

A meltdown occurs when fuel has overheated, melted, and flowed to the bottom of the reactor vessel, where it will burn its way through the steel and then collect on the floor of the primary containment structure.

It is possible to have a meltdown without a loss of primary containment; the containment is designed to hold the melted fuel and its radioactive emissions.

A loss of primary containment occurs when the integrity of the containment structure is compromised, allowing the melted fuel and/or radioactive isotopes to leak into the secondary containment. The loss of secondary containment would allow the melted fuel and/or radioactive isotopes to escape to the outside environment.

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What is a “partial reactor melt-down” and what is a “complete melt-down”?

“Meltdown” refers to damage to fuel rods due to excessive heating when the reactor’s cooling systems fail. Because of their high level of radioactivity, fuel rods in a reactor core or a spent fuel pool generate a lot of heat even if the reactor is not operating. So they must be surrounded by water that is circulated and cooled to carry heat away from the rods. If something disrupts this cooling, the fuel rods will heat up the water and eventually cause it to boil off.

If the water drops low enough to expose a significant length of a fuel rod, it will get hot enough that the zirconium cladding of the rod will start to oxidize (i.e, burn). This damage to the cladding will begin to allow the release of radioactive elements in the rod. If heating continues, the fuel pellets in the rod will start to release much larger amounts of radioactive gases. Eventually, the heat can get high enough that the fuel pellets will begin to melt. If only a fraction of the fuel pellets melt, that is called a “partial meltdown.”

A partial meltdown will release large amounts of radioactivity. In general, that radioactivity and the damaged fuel will be contained in the steel reactor vessel, which is itself in the reactor’s “primary containment” structure to isolate it from the environment. That means that even if a partial meltdown occurs, it may not lead to a large release of radioactivity into the atmosphere since it will be confined inside the reactor. That is the situation that occurred during the Three Mile Island nuclear accident in 1979.

However, if a partial meltdown occurs in spent fuel that is not in the reactor core but has been moved to the spent fuel pool, the radiation released is much more likely to get into the atmosphere. The pool is not surrounded by the same layers of confinement as the reactor. In the case of the Japanese reactors, explosions have damaged the reactor buildings and that would allow radioactive gases from the spent fuel pool to travel directly into the atmosphere.

A “complete meltdown” can occur when cooling water drops enough that the nuclear fuel in the reactor core is entirely uncovered. If a large quantity of fuel melts, the molten mass can run to the bottom of the metal reactor vessel, and may remain hot enough to burn through the vessel floor. The mass would then drop onto the concrete floor of the primary containment. In the case of the Mark I containment used in the Japanese reactors, if the mass is large enough it can spread to the metal containment wall and burn through it. If so, the containment can be breached and radioactivity will escape.

The concern about a full meltdown in the reactor is that it will potentially breach the primary containment structure, which would greatly increase the probability that it would escape into the atmosphere.

This is different for spent fuel pools. Since the pools are already outside primary containment, a complete meltdown would not necessarily be significantly worse than a partial meltdown, although the total amount of radioactive gases released would likely be larger in the former case.

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How is radioactivity released from the reactor vessel into primary containment?

Radioactive material released from damaged fuel into the reactor vessel can get into the primary containment by several different pathways.

To protect the reactor vessel and attached piping from rupturing due to high pressure, relief valves automatically open to discharge steam—and the radioactive material along with it—into the primary containment structure.

Workers may also manually open the relief valves to prevent high pressure in the reactor vessel from impeding the flow of makeup water, such as the sea water that has reportedly been injected into some of the Japanese reactors.

In addition, a steam-driven emergency system called the reactor core isolation cooling (RCIC) system uses steam from the reactor vessel to spin a small turbine connected to a pump that transfers makeup water to the reactor vessel. After the steam is used for this purpose, the steam—along with the radioactive material—is deposited into the primary containment.

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If the reactors are shut down, why is cooling a problem?

When the reactor shuts down, the fission process in the nuclear fuel stops. However, the fuel is very hot, and is still highly radioactive. When the radioactive particles decay, this produces additional heat.

When “spent” fuel is no longer useful for generating power and is removed from the reactor, it is placed in a storage pool filled with circulating, cooled water for a period of years to cool down.

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What are the risks, including fire risks, associated with spent fuel storage pools?

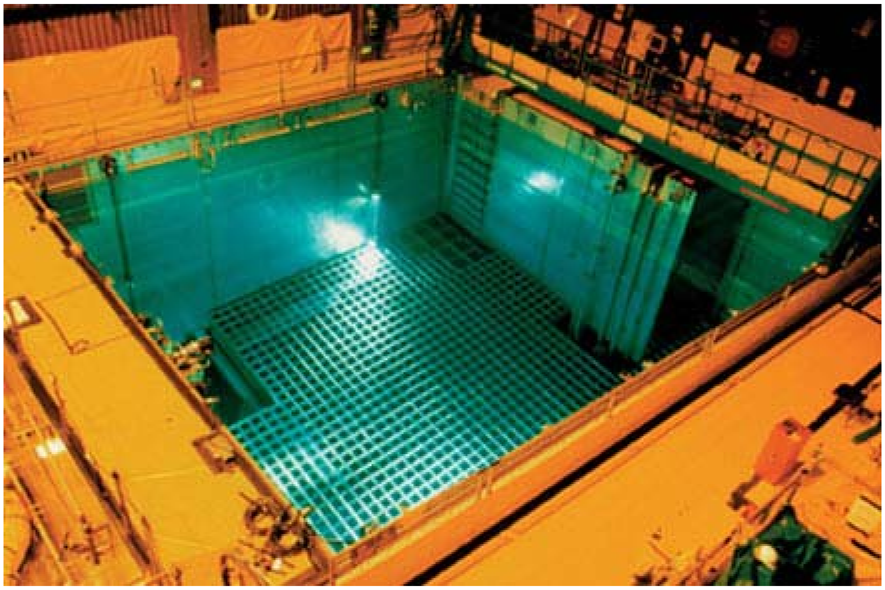
Spent fuel pools contain fuel rods that have been taken out of a reactor core. Because they are highly radioactive, they continue to generate heat and must be cooled for years. They also contain large amounts of radioactive elements, which can be released to the atmosphere if there is a prolonged interruption of cooling and the water in the pool boils off.

If the system that circulates and cools the water in the spent fuel pool stops working, the rods will begin to heat up the water in the pool and cause it to begin to boil away. If the water that boils away cannot be replaced, the water level will drop, exposing the rods. The rods will begin to heat, which can lead to damage of the rod, or possibly a partial or complete meltdown (see question above).

All of those consequences would lead to a release of radiation from the damaged rods. The amount released would depend on the severity of damage to the rod as well as the amount of spent fuel in the pool and the length of time it had been out of the reactor and has had time to cool.

Two of the radioactive gases released from fuel rods are Iodine-131 and Cesium-137. Because radioactive Iodine-131 has a short half-life (8 days) it would begin to decay away quickly once the fuel was removed from the reactor core, where it is created by fissioning of the fuel. So radiation releases from spent fuel would have much lower levels of Iodine-131. However, Cesium-137, which has a longer half-life (30 years), decays much more slowly so levels would remain high in the spent fuel. Cesium-137 is the major long-term contaminant from the Chernobyl accident, and has led to an exclusion zone around that reactor.

An important concern about spent fuel pools is that they are not isolated from the environment to the same extent that fuel in the reactor core is, since the pools are outside the primary containment structure. So even if the total amount of radiation released by damage to fuel rods in a spent fuel pool is less than that released by a similar level of damage to fuel in the reactor core, the fraction of that release that gets into the atmosphere is likely to be much higher from the spent fuel pools. Since the net release into the air will be determined by the two factors—how much radiation is released by the fuel rods and how much of that escapes to the environment— greater levels of radiation could result from the loss of cooling to a spent fuel pool than the loss of cooling to a reactor.



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What happens to the seawater that is being pumped into the reactors?

Pumping seawater into the reactor core is a last-ditch option to cool the fuel, and the water is turned into steam as it is heated up by the hot fuel. Seawater needs to be pumped in on an ongoing basis to replace the water that has turned into steam.

The heating and then boiling of the seawater causes the pressure to rise inside the reactor vessel that surrounds the reactor core. If the pressure in the reactor vessel is too high, it can impede and even prevent the pumps from being able to pump in the seawater.

To reduce the pressure in the reactor vessel, the steam is periodically vented into the containment structure surrounding the reactor vessel. This, in turn, causes the pressure inside the containment structure to rise.

To reduce this pressure, the gas in the containment has at times been vented to the atmosphere. There is radioactivity in the gas vented from containment, but venting was necessary to reduce the pressure in the reactor vessel enough to allow more seawater to be pumped in to attempt to cool the reactor core.

The *New York Times* reported on March 23 that "some of the seawater used for cooling has returned to the ocean." The source of this seawater is probably the water that has been sprayed from fire hoses and dumped from helicopters onto the spent fuel pools to try to keep the spent fuel cool. Much of that water did not end up in the spent fuel pools. This water is likely to be radioactive.

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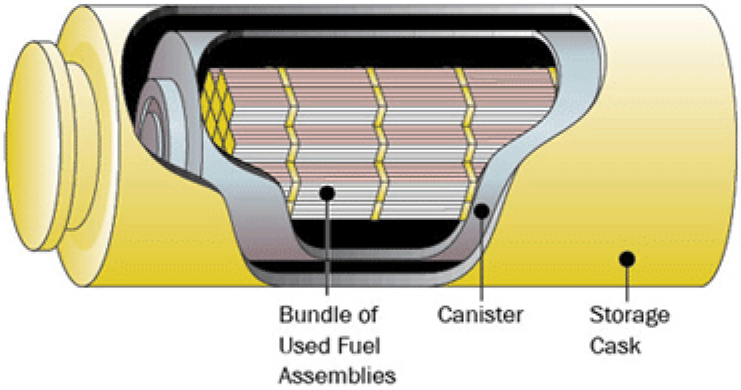
Officials are worried about radiation from the spent fuel pools in Japan because the pools are not enclosed in containment devices as reactor cores are. Are the spent fuel pools better protected at U.S. nuclear power plants?

The spent fuel pools at U.S. reactors are also outside the primary containment vessel, so they are no better protected than are the pools in Japan. Spent fuel pools actually pose more of a risk in the United States because the pools here contain more fuel than do those in Japan. The U.S. National Academy of Sciences even reprimanded U.S. plants for ignoring the hazards of spent fuel, but the warnings continue to fall on deaf ears. (See the 2006 report Safety and Security of Commercial Spent Nuclear Fuel Storage: Public Report.)

For years UCS has been calling on nuclear power plants to move their older spent fuel to storage in dry casks, where spent fuel rods are enclosed in a large steel cylindrical canister surrounded by a concrete cask with thick walls (see picture below), which greatly reduces both safety risks and those associated with terrorist attacks.

For more information see remarks by David Lochbaum, director of UCS's nuclear safety project, before the Transportation and Storage Subcommittee of the Blue Ribbon Commission on America's Nuclear Future, which will recommend what to do with U.S. spent reactor fuel. Lochbaum's remarks focused on the risks of spent fuel stored at reactor sites in wet pools and dry casks.



Source: U.S. Nuclear Regulatory Commission

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What is MOX fuel, and does its presence in Fukushima reactor #3 cause a problem?

Most reactors use uranium fuel, including all the Fukushima Dai-Ichi reactors. As uranium fuel burns, some of it is converted into plutonium, so all operating reactors have plutonium in their core. About 6% of the fuel in reactor #3 is MOX fuel, which contains about 200 kilograms of plutonium. This amount is a small enough that it will likely make no significant difference in the amount of plutonium that may escape into the environment. More info on MOX fuel.

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What is the risk to people outside the evacuated area in Japan? Should more people in Japan be evacuated?

Given the amount of radioactivity that could be released from the facility, the Japanese government was wise to evacuate residents within a 12 mile (20 kilometer) radius of the reactor site. Given the uncertainty over future releases, we believe the government should extend that evacuation zone.

On March 16, the Nuclear Regulatory Commission advised U.S. citizens within a 50-mile radius around the site to evacuate. Despite the U.S. advisory, the Japanese government is still maintaining their current order, which is evacuation only to a distance of 12 miles, and “shelter in place” for those between 12 and about 18 miles from the reactor site. “Shelter in place” means that people are directed to stay indoors and seal their windows and doors.

Our assessment is that the Japanese government is squandering the opportunity to initiate an orderly evacuation from larger areas around the site—especially of sensitive populations, like children and pregnant women. It is potentially wasting valuable time by not undertaking a larger scale evacuation at this time.

NOTE: The *New York Times* reported on March 25 that the Japanese government had begun "quietly encouraging" and assisting residents to evacuate from an expanded area around the Fukushima Daiichi nuclear plant. According to the *Times* article, the voluntary evacuation zone has been expanded to include the area between 12 and 19 miles from the plant, where residents had previously been advised to "shelter in place."

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The Japanese government has told people between 12 and 18 miles from the Fukushima plant to stay indoors—how long are they expected to stay there?

People who have been told to "shelter in place" are expected to remain indoors until there is no longer a risk that the plant will emit more radiation.

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The Japanese workers at the Fukushima plant have been limited to an exposure of 250 milliSieverts. Is that the limit for a one-time dose, or a cumulative limit?

It is an annual limit.

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What are radioactive isotopes, and which ones are of most concern in a nuclear power accident?

Radioactive materials decay, releasing particles that can damage living tissue and lead to cancer. Some elements have different forms, called isotopes, that differ in the number of neutrons in the nucleus.

The radioactive isotopes of greatest concern in a nuclear power accident are iodine-131 and cesium-137. Iodine-131 has a half-life of 8 days, meaning half of it will have decayed after 8 days, and half of that in another 8 days, etc. Therefore, it is of greatest concern in the days and weeks following an accident. It is also volatile so will spread easily.

In the human body, iodine is taken up by the thyroid, and becomes concentrated there, where it can lead to thyroid cancer in later life. Children who are exposed to iodine-131 are more likely than adults to get cancer later in life.

To guard against the absorption of iodione-131, people can proactively take potassium iodine pills so the thyroid becomes saturated with non-radioactive iodine and is not able to absorb any iodine-131.

Cesium-137 has a half-life of about 30 years, so will take more than a century to decay by a significant amount. Living organisms treat cesium-137 as if it were potassium, and it becomes part of the fluid electrolytes and is eventually excreted. It can cause many different types of cancer.

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Is there a threat to Americans in Hawaii, Alaska, or the U.S. West Coast? Should residents of these areas take potassium iodide pills to protect against thyroid cancer?

No. While wind patterns will likely carry the radioactive plume eastward, since Japan is thousands of miles from the United States, radioactive material in the air will be so diffuse by the time it reaches Hawaii, Alaska, or the mainland United States that it is highly unlikely to create significant health concerns.

As a result, people in those locations will not have to worry about direct inhalation of a radiation plume, which is the kind of exposure potassium iodide (KI) pills are most effective against.

Americans could also be exposed to radioactive iodine if agricultural products were contaminated. Radioactive iodine could be ingested by dairy cows, for example, and then would be concentrated in milk. Potassium iodide, however, would not be effective in that situation. Moreover, federal and state health authorities would test for such contamination and could take products off the market if necessary.

The people of Japan should be given priority access to KI pills. Indeed, if there is a run on medication in the United States, or elsewhere, there might not be enough left for Japanese residents who truly need it.

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Why is potassium iodide (KI) effective against inhalation of radioactive iodine, but not against ingestion via, for example, milk?

According to the 2004 National Academy of Sciences study on Distribution and Administration of Potassium Iodide in the Event of a Nuclear Incident:

“Exposure to radioactive iodine is possible through the ingestion pathway, so it is important that plans address this situation. Monitoring of the environment and food products controls this route of exposure. Removing contaminated products from the market and isolating contaminated products until the radioactive iodine decays to safe levels are the most effective way to eliminate radiation exposure and damage to the thyroid. That also eliminates the need for the use of KI by the general public as a protective action.”

Potassium iodide can only reduce the risk from radioactive iodine that has entered the body, not eliminate it. People in the radioactive plume do not have the option of not breathing, so taking potassium iodide is an effective countermeasure against inhalation. However, people have the option of not drinking contaminated milk or eating other contaminated food products. In comparison, taking potassium iodide would be less effective.

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Can you be exposed to dangerous levels of radiation flying across the United States due to the radiation released in Japan?

No. As noted in the previous question, since Japan is thousands of miles from the United States, radioactive material carried by the wind to Hawaii, Alaska, or the mainland United States will be so diffuse that it is highly unlikely to create significant health concerns. This is true whether you are on the ground or in an airplane.

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Can plants in the United States withstand disasters such as the earthquake and tsunami that crippled nuclear reactors in Japan?

Some U.S. reactors are sister plants to the Fukushima Unit 1 reactor, which is a boiling water reactor (BWR) of General Electric design, and they are operating under similar regulations. If confronted with a similar challenge, it's folly to assume the outcome would not also be similar.

U.S. plants have the same key vulnerability that led to the crisis in Japan. The basic problem is that the Japanese reactors lost both their normal and back-up power supplies, which are used to cool fuel rods and the reactor core. The reactors had batteries that could supply power for eight hours until the back-up system or normal power supply was restored. But officials were unable to fully restore either. Most U.S. reactors are designed to cope with station power outages (where both primary and back-up power supplies are out) lasting only four hours. Measures that increase the chance of restoring power within the four-hour time period, and provide better cooling options if that time runs out, would make U.S. reactors less vulnerable.

In addition, we know that earthquakes can cause fires at nuclear reactors, and U.S. reactor safety studies conclude that fire can be a dominant risk for reactor core damage by disabling primary and backup emergency systems. Yet dozens of nuclear reactors in the United States have operated for years in violation of federal fire protection regulations, with no plans to address these safety risks any time soon.

Finally, reactor emergency plans in the U.S. assume that a reactor accident would be the only demand on emergency response resources. The accident in Japan is another reminder of the need to revisit emergency plans to ensure that emergency responders are able to respond to both the problem at the power plant and the nearby community’s needs.

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Are the leaks at Indian Point a problem?

There are two leakage problems at the Indian Point nuclear reactor in New York, which are getting confused.

There is a small leak from one of the spent fuel pools at Indian Point. That small leak is not a problem; the plant is adding water to make up for the leaking water. If there was a situation where there was no power or back-power at the plant, the leak would only make things incrementally worse. The real problem would be the water boiling off the surface of the spent fuel pool.

There is also a known leak through the refueling water cavity liner (see our recent report for a fuller description). The liner is not in the spent fuel pool at Indian Point; it is in an adjacent area. That liner was installed to prevent leakage in the event of an earthquake. Should an earthquake occur, that liner cannot perform its safety function since it is already known to be leaking.

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Would reprocessing reduce the overcrowding in U.S. spent fuel pools and lead to safer nuclear power?

Reprocessing would increase the risk of nuclear terrorism and add to the nuclear waste problem. The problem of overcrowded spent fuel pools can best be addressed by transferring the spent fuel to dry casks once it has cooled enough.

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Will new reactors be safer than existing ones?

Some argue that new reactor designs on the drawing board will be safer and more secure against terrorist attacks than today's generation of reactors. It is true that new reactors could be designed to be safer than today's plants, and much more resistant to sabotage and attack. However, the long-standing policy of the Nuclear Regulatory Commission (NRC) is to *not* require new designs to be demonstrably safer than existing ones. Without this requirement, the extra expense associated with safer design features means that designers will cut safety corners and that safer designs will lose out in the marketplace.

In the United States, several new reactor designs are under consideration: the General Electric Advanced Boiling Water Reactor (ABWR) and Economic Simplified Boiling Water Reactor (ESBWR); the Mitsubishi Advanced Pressurized Water Reactor (APWR); the Westinghouse AP1000; and the Areva Evolutionary Power Reactor (EPR).

The ABWR and APWR are similar to current reactors. The ESBWR and the AP1000 include passive safety features that could make the reactors significantly safer, but there are large uncertainties in how these systems would work in practice, so the reactors may not be safer. Moreover, the designers have reduced defense-in-depth—presumably to cut costs. These two designs have less robust containment systems, less redundancy in safety systems, and fewer safety-grade structures, systems, and components.

The EPR stands apart from these other designs. While it has some safety downsides, this design fulfills more stringent French and German safety criteria and has considerably greater safety margins than designs developed to meet only NRC standards. For example, the reactor has a double-walled containment structure, whereas the NRC requires only a single-walled one. However, this design is more expensive than the others described here and has not found any buyers in the United States.

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