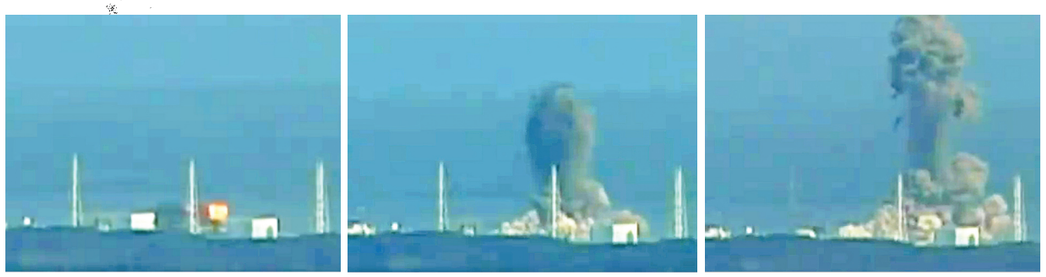
PHYSICAL

NEW NUKES

Can nuclear power survive this year's disastrous meltdown in Japan?

By Bobby Oerzen



This photo sequence shows the hydrogen explosion that ripped through the nuclear power plant near Fukushima, Japan, last March.

Late last spring, a magnitude 9.0 earthquake rocked northeastern Japan. Less than an hour later, a 46-foot tsunami triggered by the quake crashed into the Japanese coast.

The double disaster disrupted operations at a nuclear power plant located on the coast, just south of the city of Fukushima. Systems designed to keep the plant operating safely failed. The damage done to the plant and the contamination released into the environment made the accident a Level 7 nuclear disaster, one of the worst in history.

The event reawakened fears about nuclear energy, not only in Japan but also around the world. The German and Swiss governments issued statements renouncing the power source, vowing to stop using it by 2034. In the United States, public support for nuclear power dropped from 60 percent to 40 percent.

Once again, the world was reminded of the troubling trade-offs of nuclear power. Although nuclear reactors are capable of producing tremendous amounts of energy, they also possess an enormous capacity for destruction should something malfunction. Will new, improved reactor designs and safety systems be sufficient to ease public anxieties about nuclear power?

NUCLEAR EVOLUTION

The world's first nuclear reactor came on line in 1954 in the Soviet Union. Today, despite long-standing fears, nuclear energy production is at an all-time high. In France, nuclear energy supplies the country with 75 percent of its electricity. The United States has 104 plants producing 20 percent of its electricity.

Nuclear energy has evolved over the years. "[Nuclear power is] like any technology," says Scott Peterson, senior vice president of the Nuclear Energy Institute, an industry trade group. "Just think of the microchip. Over time, it's become better, more powerful. The same is true of nuclear energy."

The earliest nuclear plants were called Generation I reactors. Generation II plants were built from the 1960s to the 1990s. The Fukushima plant was Generation II. Now Generation III reactors are coming on line. Many of the changes made from one generation to the next were for safety reasons.

BOILER ROOM

A nuclear plant is, essentially, an extraordinary heat source. The heat changes water into steam. (Imagine a giant boiler room.) The steam rises and spins a series of turbines, which generate the electricity.

The heat in a nuclear plant rises from solid fuel rods, which contain a form of uranium called uranium-235. Like other forms of uranium, uranium-235 is *radioactive*—it releases high-energy particles and rays that can damage living things.

In a nuclear reactor, uranium-235 undergoes *induced fission*. It's bombarded with neutrons, which cause its atoms to become very unstable and split apart. That splitting releases a tremendous amount of energy, which is used to heat the water and turn it into steam. Once fission begins, it sets off a chain reaction in the uranium that can't be stopped.

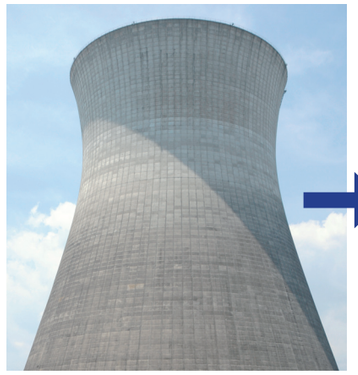
That chain reaction is the primary danger in a nuclear plant. It can lead to a *meltdown*. The heat released by the chain reaction exceeds the heat removed by the plant's cooling system. The overheated reactor ruptures, and radioactive material is released into the environment. When a nuclear plant near the Ukrainian city of Chernobyl melted down in 1986, a wind-borne cloud of radioactive material traveled thousands of miles.

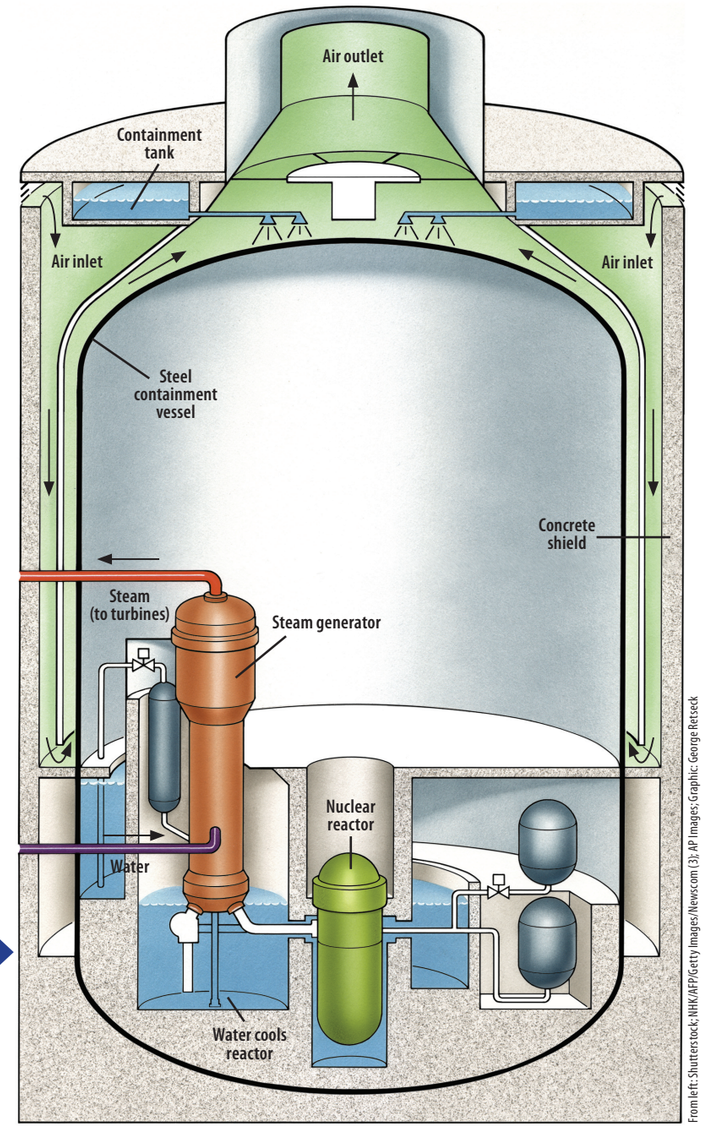
WATER COOLER

The cooling systems in Generation II reactors run on electricity. The March 11 earthquake knocked out the Fukushima plant's connection to the electrical grid that supplies electricity to the region.

An hour later, the tsunami destroyed the plant's backup diesel generators, which were designed to provide an emergency supply of electricity to the cooling system. The plant had absolutely no electricity to keep cool water flowing through the reactor. That caused explosions, spreading radiation through the countryside.

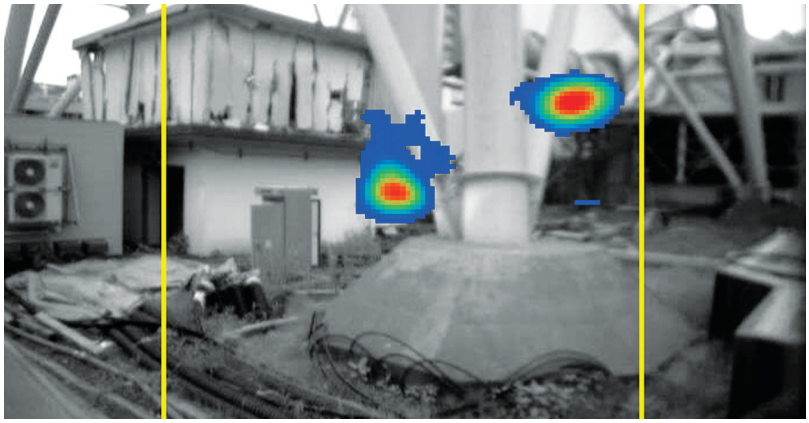
Generation III reactors have safety features that don't need electricity to function. The most notable one is a 3 million-liter (800,000-gallon) water tank that sits directly above the reactor shell. The tank has valves that remain shut so long as electricity is running through them. In the event





From left: Shutterstock; NHK/AFP/Getty Images/Newscom (3); AP Images; Graphic: George Retseck

Left: A nuclear power plant's huge cooling tower transfers waste heat to the atmosphere. Right: In a Generation III plant, heat generated by the nuclear reactor converts water into steam, which spins a series of turbines that generate electricity. Waste heat from the reactor is absorbed by water and air that circulate around the reactor. In the event that those cooling systems fail, water spills downward from a containment tank, keeping the reactor from overheating for three days.



This is an image, taken by a gamma-ray camera, of one part of the damaged Fukushima nuclear power plant in Japan. The colored patches indicate where lethal levels of radiation are leaking from the plant.

of an electricity failure, the valves open automatically. Water flows downward, cooling the reactor. "Essentially, you're using gravity as your backup system," says Peterson.

The water tank and other modifications keep Generation III reactors cool and meltdown-free for at least three days after a loss of electricity. That's a vast improvement over Generation II reactors, which have a shorter window of four to eight hours before meltdown.

China is building 29 Generation III plants. Europe is building six. And two are planned for the United States—one in Georgia and one in South Carolina.

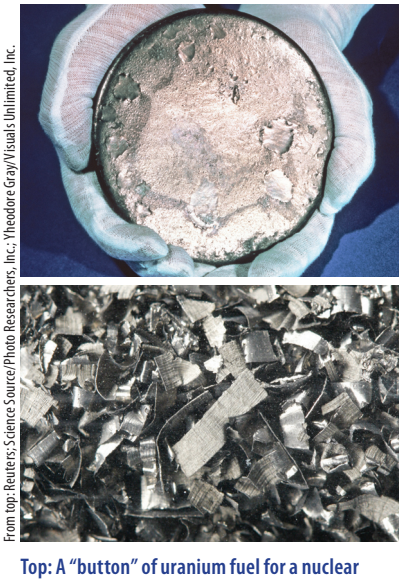
THE NEXT GENERATION

Generation III reactors can still melt down, and some critics believe that any such threat is too much for a society to bear. The environmental group Greenpeace has condemned nuclear energy as an "inherently dangerous technology that should be phased out and replaced."

An even newer breed of reactors—Generation IV plants—might silence those critics. One type of Generation IV reactor would run on *thorium*, a silvery element that's four times as abundant as uranium. Thorium is also less radioactive, making it easier to mine and cleaner to process.

John Kutsch says thorium reactors are the "inverse" of uranium reactors. Kutsch is executive director of the Thorium Energy Alliance. By *inverse*, Kutsch simply means that the thorium fuel in the reactor would be in a liquid, not solid, state. Only when thorium is liquid can fission occur. Liquid thorium also releases twice as much heat as uranium and leaves much less radioactive waste.

A thorium reactor would also be cooled by air, not water—another advantage over uranium, says Kutsch. In a uranium reactor, the cooling system must be kept at very high pressures. "It's so high that it can actually rip the hydrogen atoms off of the water molecules," comments Kutsch. The buildup of hydrogen gas puts a uranium reactor at high risk of hydrogen explosions. Such explosions tore through the Fukushima plant when it malfunctioned in March.



From top: Reuters; Science Source/Photo Researchers, Inc.; Theodore Gray/Visuals Unlimited, Inc.

Top: A "button" of uranium fuel for a nuclear reactor. Bottom: Shavings of thorium

What if a thorium plant were to lose electricity, shutting down its cooling system? The heat from the thorium would melt a frozen plug of salt installed at the bottom of the reactor. The thorium would drain out of the reactor and harden, stopping the fission reaction and preventing a meltdown.

"Think of it like a candle," explains Kutsch. "If your cat accidentally knocked the candle over, and the flame went out, the wax would just spill on the floor and harden. It may cause a bit of a mess, but it *won't* cause an explosion or nuclear meltdown."

"Walk-away safe," is how Kutsch describes thorium reactors. "They're wonderfully elegant."

ENERGY DEMAND

It's a hard, cold fact that the industrialized world has a gargantuan appetite for energy. That demand is exploding as countries such as China and India modernize.

Where will all that energy come from? Nuclear power is an extremely concentrated source of abundant electricity. One nuclear power plant provides the energy equivalent of 52 square kilometers (20 squares miles) of solar panels, 1,200 windmills, or the entire Hoover Dam.

Nuclear power has obvious risks, but so do coal and oil, the top sources of greenhouse gases in the world. It is the enormous rise in those gases that scientists hold responsible for global warming. "[Nuclear power] accounts for 70 percent of America's energy that doesn't produce greenhouse gases," Peterson points out.

The world has landed in a fix that it may take the rest of this century to get out of. How do we find abundant sources of energy that don't imperil the environment? Is risk-free energy even possible? If not, which risks are we prepared to live with? **CS**